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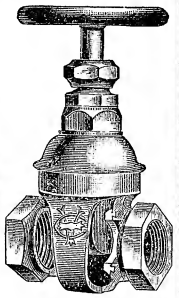
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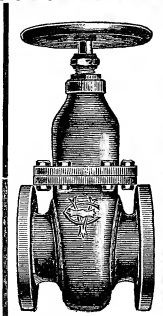
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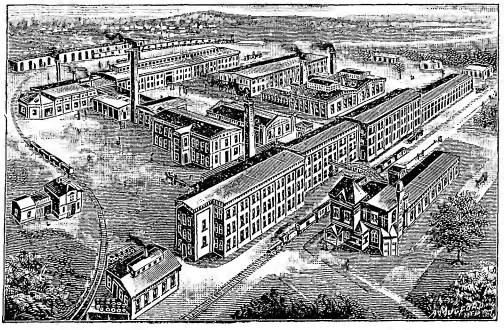
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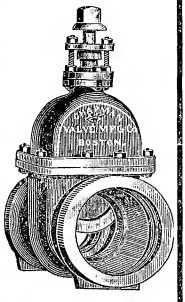
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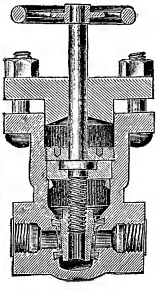
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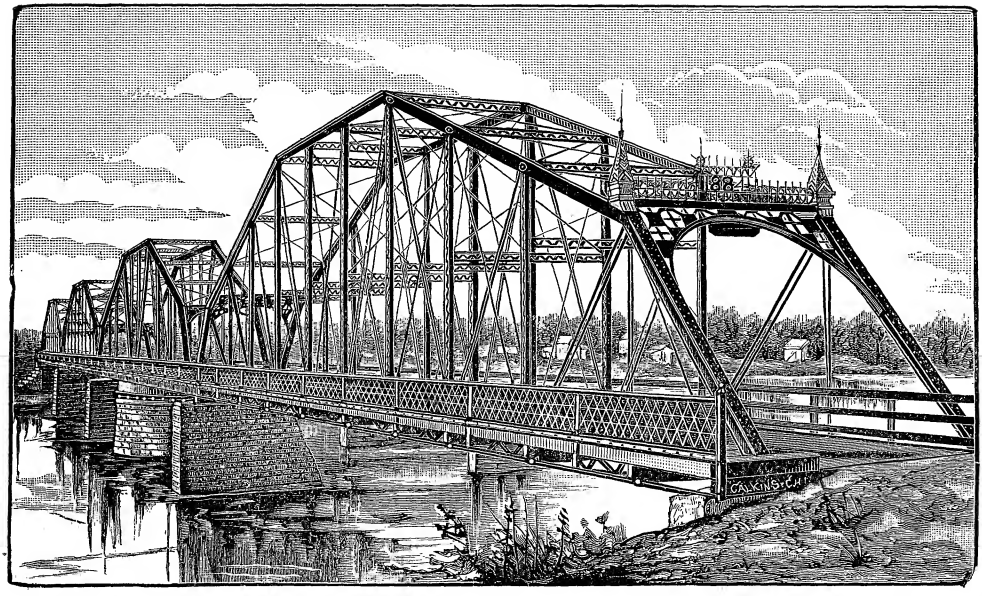
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THE NEW ENGINEERING BUILDING.

This handsome building, for which $160,000 was appropriated by the last legislature, will be ready for use by the first of next fall term. Plans were asked for by the trustees from the graduates of the architectural department of the University of Illinois. The first prize was awarded to Mr. G. W. Bullard of Tacoma, Wash., who was made architect of the building. It is a matter of pride to the University that one of her graduates should have furnished the plans for the imposing building which forms the subject of our frontispiece.

The frontage of the building is 200 ft.; depth of wings, 76 ft.; depth in center, 138 ft. The middle wing is 72 feet wide. The first story is of drab sandstone laid in 12-inch courses and having tooth-chiseled finish and deeply champfered joints. The three upper stories are of buff pressed brick with terra cotta trlmmings to match. Slow burning mill construction is to be used in the interior of the building. The ceilings will be finished in Washington fir, and the remainder of the interior in oak with bronze trimmings.

The first story of the west and central wings will contain the laboratories of the department of electrical engineering, while the east wing is to be devoted to the masonry laboratory and the instrument room of the civil engineering department. The central wing of the second story will be taken up by the lecture room and preparation room of the department of physics, and the remainder of the floor is to be used by the departments of civil and municipal engineering for recitation and drawing rooms, cabinets and studies. The middle wing of the third story will contain the laboratories of the department of physics, while in the side wings are to be the drawing rooms, lecture rooms, cabinets and studies of the mechanical engineering department. The central portion of this floor will contain the library, office and faculty parlors. The fourth story is to be taken up entirely by the department of architecture and the blue print laboratory.



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CIVIL ENGINEERING DEPARTMENT.

A FEW PRINCIPLES OF DESIGN OF METAL SKELETONS FOR TALL BUILDINGS.

By Peter Mogensen, '94.

I.—Wind Bracing.

It has been common practice in the past to make no special provision for the resistance of wind stresses in tall buildings, but as the evolution in such buildings goes on, with a marked tendency to increasing height of structures, engineers and architects are becoming convinced of the necessity and propriety of employing adequate wind bracing, and of designing all parts, at least as far as the metal skeletons are concerned, in accordance with the principles of engineering science.

The determination of wind stresses in a few types of bracing will be here attempted. Owing to the large number of indeterminable factors which enter into the computations, and the consequent equal number of assumptions that must be made, the problem is not capable of exact solution.

The stresses in the wind bracing will be greatest when the direction of the wind is normal to an outer wall and parallel to the plane of the bracing, therefore this condition will be assumed throughout the discussion. It is further assumed that the floors are sufficiently rigid to transmit the wind strains, and no investigation of the horizontal connections between columns will be undertaken. The magnitude of the wind pressure will be

$$P = p\,H\,L, \quad \ldots\ldots\ldots \quad (1)$$

where P is the resultant pressure, p the pressure per unit area,

and H and L the height and width respectively of the area tributary to the bracing under consideration. Certain classes of roofs and sheltered positions may in some cases necessitate a modification of the above formula.

By reason of the present lack of knowledge as to the extent to which floors, partitions, linings, joints, coverings, etc., are capable of resisting wind pressure, these sources of strength will be disregarded, with the exception of the capability of tne floors to transmit wind strains as before stated.

A. Let Fig. 1 represent the center lines of the members forming the skeleton of a partition containing wind bracing. Then, beginning with the upper story

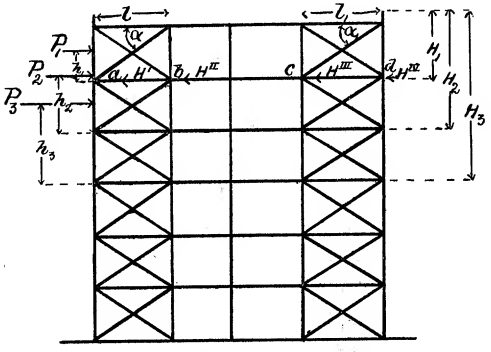


Fig. 1.

$$P_1 = p\, h_1 L,$$

in which the nomenclature is the same as that used in eq. (1), adapted to a certain story as denoted by the subscripts and indicated in the figure. The height h_1, from the floor to the story considered, at which P_1 acts is equal to $\frac{H_1}{2}$. The horizontal shear due to this force will be resisted at a, b, c, and d, by the forces H^{I}, H^{II}, H^{III}, H^{IV}. The relation between these forces can not be determined, but it is rational to *assume* that they are equal, or if there are n bays braced instead of two as in Fig. 1, we have

$$H^{\text{I}} = H^{\text{II}} = H^{\text{III}} = \cdots\cdots H^{2n} = \frac{P_1}{2n} \quad . \quad . \quad . \quad . \quad (2)$$

The tension T_1 in any diagnal member in action, making an angle α with the horizontal, is given by the formula

$$T_1 = H^1 \sec \alpha = \frac{P_1}{2n} \sec \alpha, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

There will be a decrease in load on the windward column and an equal increase in load on the leeward column of each braced bay, equal to

$$W_1 = \frac{P_1 \ h_1}{nl}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

in which W_1 is the decrease or increase in load above referred to, l the width of any bay considered, and P_1, h_1, and n as before explained.

The stresses in the second story from the top can be found by substituting P_2 and h_2 for P_1 and h_1 respectively in the formulas (3) and (4). In a similar manner the stresses in any story may be determined by the insertion in the formulas of the corresponding values of P and h It should be noticed that the values of T and W will vary with that of l, the width of the bay.

B. If all bays are braced the tension in the diagonals will still be

$$\frac{P}{2n} \sec \alpha ,$$

but all the columns on the windward side of the neutral axis, Fig. 2, will be relieved, and those on the leeward side will re-

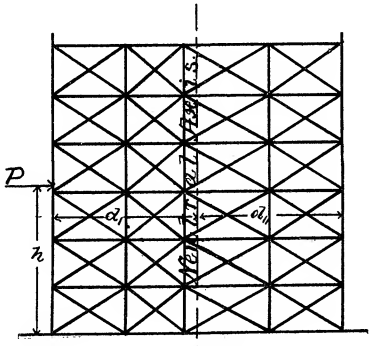


Fig. 2.

ceive additional load. This change of load W is found by the equation

$$\Sigma \frac{d_{,}}{d_{,,}} \frac{W}{d} z^2 = Ph,$$

from which

$$W = \frac{Ph}{\Sigma \frac{d_{,}}{d_{,,}} \frac{z^2}{d}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

where W is the increase or decrease in load on the remotest columns, $d_{,}$ and $d_{,,}$ are the distances of the remotest columns from the neutral axis, d is a general expression for these distances, z is the distance of any column, and Σ is the familiar sign for summation. The value of W will vary directly with z. Thus the framework is considered a cantilever beam with all its resisting fibres concentrated at the centers of the columns.

When two or more *adjacent* bays are braced this method of computing the increase and decrease in column load should be employed.

C. In Fig. 3 is represented a different arrangement of wind bracing. The corner at o is shown in Fig. 3*a* on a larger scale.

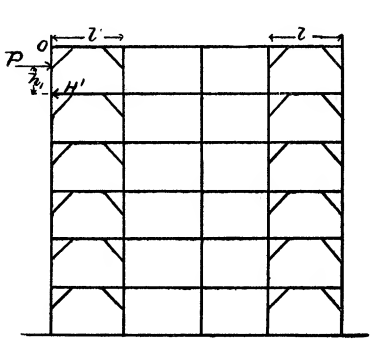


Fig. 3.

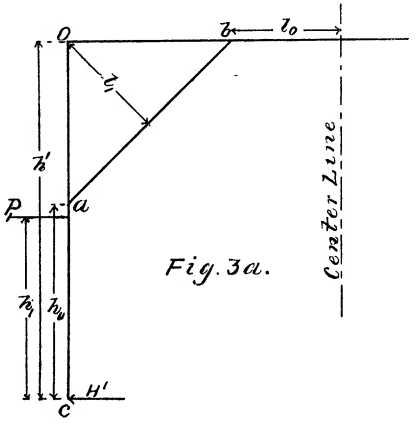


Fig. 3a.

If n bays are braced, as in **A**, then from equation (2)

$$H^1 = \frac{P_{,}}{2n}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

and from equation (4)

$$W_1 = \frac{P_1 h_1}{nl}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

and the tension in the brace $a\ b$ is nearly

$$T = \frac{P_1}{2n} . h^{\mathrm{I}} . \frac{1}{l_1} = \frac{P_1 h^{\mathrm{I}}}{2l}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

for which the nomenclature is as indicated in Fig. 3*a*. There will be the same amount of compression in the opposite corner, which suggests the employment of braces capable of resisting both compression and tension. A bending moment will be produced at a whose value is approximately, but sufficiently accurate for the present purpose, from equation (2),

$$M = H^{\mathrm{I}} \frac{h^{\mathrm{II}}}{2} = \frac{P_1 h^{\mathrm{II}}}{4n}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

The factor $\frac{h^{\mathrm{II}}}{2}$ is used as the column is considered square ended and fixed by the static load and by bolts. A bending moment equal to M will also exist at c. There will further be a bending moment M_1 at b expressed by the equation

$$M_1 = W_1 l_0 = \frac{P_1 h_1 l_0}{nl}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

Again as in **A**, the stresses in any other story may be found.

D. When stiffening portals, outlined in Figs. 4 and 7, are

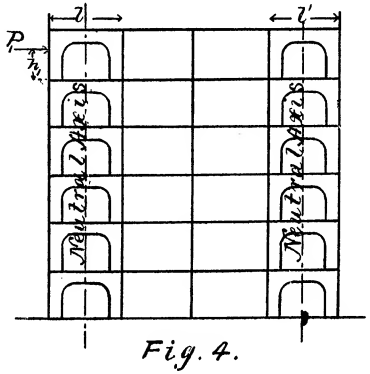


Fig. 4.

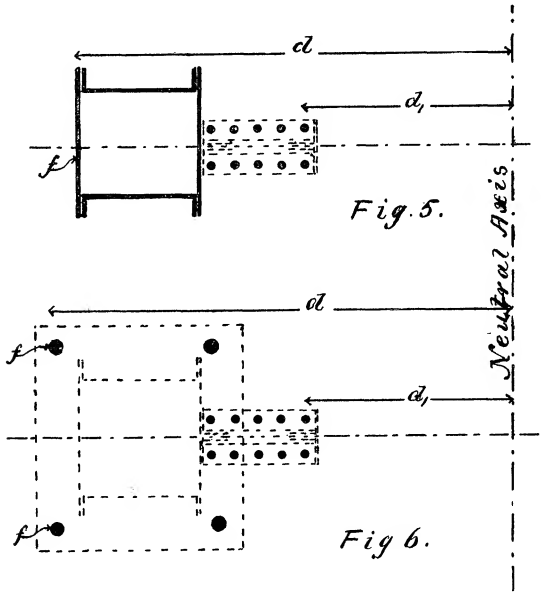
used, and n is the number of bays braced, there is produced at the floor level of any story considered a wind moment M which is as before

$$\frac{P}{n}h.$$

But owing to the rigidity of the framework this wind moment is resisted by the resisting moment of the sections of columns and portal, one on either side of the neutral axis. This resisting moment is

$$\frac{SI}{d},$$

where S is the unit stress on the remotest fibre, f



(Figs. 5 and 6) of column and bolts; d is the distance of the fibres from the neutral axis; I is the moment of inertia of—1st, on the compression side of bay—a section of column and portal, and—2d, on the tension side—a section of the column and of the bolts securing portal to floor beam, indicated by black tints in Fig. 5. If a splice occurs in the column the

section on the tension side will consist of the partial sections of bolts in cap or sole plate and the bolts through portal and floor beam already mentioned, Fig 6. Generally the neutral axis for this moment of inertia will not be coincident with the center line of the bay, although ordinarily it will not be far removed from it. Hence

$$M = \frac{P}{n}h = \frac{SI}{d'}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

and

$$S = \frac{Phd}{nI}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

Further the decrease of load on one side and the increase of load on the other side of the neutral axis is

$$R = \lesssim_{d_1}^{d} S_v, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

with the values of d and d_1 as indicated in Figs. 5 and 6, and S_v the varying unit stress between these limits of d. R therefore, is the sum of the lifting tendencies on one side, or the aggregate downward pressure, due to the wind force on the other side of the neutral axis. This additional load R is not to be considered as affecting the columns alone. As the portal is firmly attached to the columns and stiffened by angles it is fair to assume that the portal takes its proportional share of the load.

There will be a shear at g,

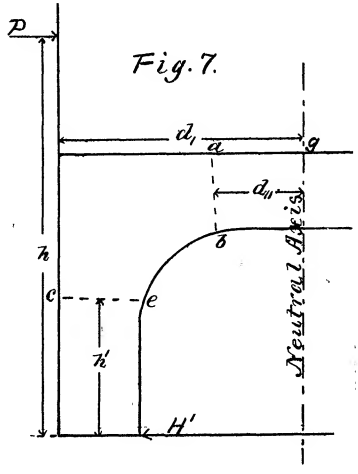


Fig. 7, whose value is approximately

$$S_s = \frac{R}{m}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

m being the number of the story considered, counting from the top.

A bending moment

$$M_{\text{I}} = S_s d_{\text{II}} = \frac{R d_{\text{II}}}{m}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

must be resisted by the section $a\ b$.

Further, a bending moment equal to

$$M_{\text{II}} = \frac{H' h'}{2} = \frac{P h'}{4 n}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

is to be resisted by the section of column and portal through $c\ e$. The location of this section where the greatest unit stress is produced can easily be found with sufficient accuracy in one or two trials.

There will also be a bending moment equal to M_{II}, equation 16, acting at floor level.

II.—The Design of Connections Between Beams and Columns.

When a beam rests on a bracket attached to a column by means of bolts or rivets, the latter should be of sufficient size and number to withstand the shear caused by the weight of the beam and its load. But if the beam is riveted to the column, then a bending moment on the rigid joint thus formed is to be resisted. This occurs when, for example, the end angles of a plate girder are riveted to a box column, or when the web plate of a built beam is riveted between the longitudinal flanges of a Phœnix column.

If the beam is considered fixed at both ends the bending moment above mentioned will be for uniform load

$$\frac{wl^2}{12},$$

in which w is the load per unit of length, and l is the length of the beam.

For a load P at the middle the bending moment is

$$\frac{P\,l}{8}.$$

If the rivets are placed symmetrically above and below the neutral axis of the beam, and the resistance of each rivet to tension or shear, and of each rivet or surface in rivet hole to crushing is S, the distance of the remotest rivet from the neutral axis is d, the distances of the other rivets are z_1, z_2, *etc.*, and z is a general expression for the distance of any rivet, then the resisting moment of the joint will be

$$2\left(\frac{S}{d}z_1^2+\frac{S}{d}z_2^2+etc.,\right)=2\,\Sigma\frac{S}{d}z^2. \quad . \quad . \quad . \quad . \quad (1)$$

Hence

$$2\frac{S}{d}\Sigma z^2=\frac{wl^2}{12}=\frac{Pl}{8},$$

and

$$S=\frac{d\,w\,l^2}{24\,\Sigma z^2}=\frac{d\,P\,l}{16\,\Sigma z^2}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

If there are n rows of rivets the resisting moment will be

$$2\,n\,\Sigma\frac{S}{d}z^2,$$

and

$$S=\frac{d\,w\,l^2}{24\,n\,\Sigma z^2}=\frac{d\,P\,l}{16\,n\,\Sigma z^2}. \quad . \quad . \quad . \quad . \quad . \quad (3)$$

When the rivets are not symmetrically distributed with reference to the neutral axis of the beam, the resisting moment must be computed about a neutral axis perpendicular to the web

of the beam and passing through the center of gravity of all the rivets in the joint under investigation. The position of this neutral axis may not be the same for the rivets in tension, the rivets subject to shear, and the parts liable to fail by crushing.

The stress S thus found should not exceed the allowable working tensile or shearing stress of the rivets, or the crushing stress of the rivets and of the metal surrounding the rivet holes in plates and angles.

III.—Eccentric Loading on Columns.

A column will possess its greatest carrying capacity when the resultant line of action of the loads supported coincides with with the longitudinal axis. To this condition the ordinary column formulas apply. It is, however, often necessary to place a column under eccentric loading, *i. e.* loads whose resultant does not coincide with the neutral axis. The effect of such loading will be here investigated.

Let two lines at right angles to each other and dividing the section of a column into symmetrical parts be taken as coördinate axes, Fig. 8. Let the loads be w_1, w_2, etc., and let the abcissas

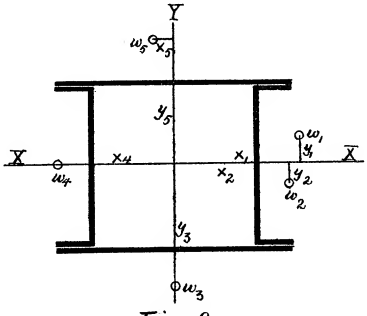


Fig. 8.

and ordinates of the points of application of these loads be x_1, x_2, etc., and y_1, y_2, etc., respectively. Then the resultant bending moment is

$$\sqrt{(\Sigma w x)^2 + (\Sigma w y)^2}.$$

This bending moment is constant throughout the column.

The resisting moment of the column is to be computed about

a neutral axis perpendicular to a line drawn through the center of gravity of the section and a point whose abcissa and ordinate are Σwx, and Σwy, respectively. This resisting moment is

$$\frac{SI}{d},$$

in which S and d are the unit stress on, and the distance of the remotest fibre from the neutral axis respectively, and I is the moment of inertia of the section.

We have then

$$\frac{SI}{d} = \sqrt{(\Sigma wx)^2 + (\Sigma wy)^2}$$

and

$$S = \frac{d\sqrt{(\Sigma wx)^2 + (\Sigma wy)^2}}{I}.$$

The allowable working stress given by an ordinary column formula should be reduced by the quantity S computed as shown above. In the application of the column formula to the computation of this working stress the moment of inertia must be found about the same neutral axis as that about which the resisting moment to eccentric loading was taken.

In practice the forces causing eccentric loading on columns are usually transmitted through beams and girders carrying walls, floors, etc. Such beams and girders are ordinarily supported in the planes of the axes of symmetry of the column corresponding to the coördinate axes, Fig. 8, and the problem is thereby somewhat simplified.

It will be noticed that the application of the lighter loads at greater distances from the center than those of the heavier loads will reduce the eccentricity, and complete concentricity of unequal loads may be produced in some cases by this means.

The determination of the points of application of the loads will in many cases be attended with difficulties, and the location of these points will vary with design and workmanship, but the good judgment of the engineer should be sufficient guide to a proper solution of the problem.

TURNTABLE FROGS.

By Milo S Ketchum, '95

In the design of locomotive round houses the tracks radiating from the turntable may be arranged in one of several ways, depending upon the length of the turntable and the amount of the stall angle. The more usual cases are: (1) for round houses of large size, the relation of stall angle to radius of turntable pit is such as to cause the nearer rails of adjacent tracks to intersect and thus require the use of frogs; and (2) for round houses of smaller size, the above relation is such that the rails do not intersect. A special case of (1) is that where the gage lines intersect at the edge of the turntable pit, but this arrangement is objectionable because of the much increased wear from the blows received as engines leave the table and also on account of the increased tendency to derailment. When frogs are used it is best to select such a stall angle as will throw the frog point back a distance sufficient to give a full rail section at the edge of the pit. This need of avoiding the weakening of the rail at the edge of turntable pit makes it advisable not to cut the rail at all, unless a proper frog is used as above suggested; and it is better to make the outer flange corners of adjacent tracks just touch at the edge of the pit if it is possible to increase the stall angle the necessary amount. This is a special case of (2) and is much used for smaller round houses and shorter turntables.

The object of this paper is to investigate the relations of the various parts and obtain formulas and tables that will facilitate the proper design and arrangement of tracks in a round house.

In Fig. 1, C is the center of the turntable. L M N is the face of the rim wall of the turntable pit. A C and B C are the center lines of two adjacent radial tracks, the corresponding intersecting gage lines of which are E E′ and D D′. F is the point where these gage lines intersect.

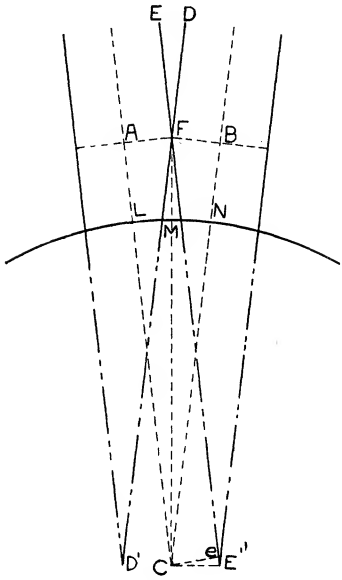


FIG. 1.

The following nomenclature will be used:

F = angle $E\ F\ D$ = angle $A\ C\ B$ = angle of intersection of two tracks = frog angle when frogs are used.

$G = 2\ A\ F = 2\ F\ B$ = gage of tracks.

$R = L\ C = M\ C$ = radius of rim circle.

$D = C\ F'$ = distance from center of turntable to point of intersection of gage lines. (In Fig. 1 the adjacent gage lines intersect outside of the rim circle.)

$d = F\ M$ = distance from rim circle to the point of intersection of gage lines, F.

$w = L\ N$ = distance between centers of tracks on rim circle, measured on the chord.

N = number of frog.

b = width of base of rail.

h = width of head of rail.

Then in Fig. 1, we have by trigonometry:

$$C\ F = A\ F \csc A\ C\ F$$
$$D = \tfrac{1}{2}\ G \csc \tfrac{1}{2}\ F \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

From the definition of the number of a frog we have

$$N = \frac{C\,F}{D'E'} = \frac{D}{G} \quad (approx.)$$

from which

$$D = N\,G \quad . \quad . \quad . \quad (approx.) \quad . \quad . \quad . \quad (2)$$

$$d = D - R \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

$$L\,N = 2\,L\,C\,sin\,F\,C\,A$$

$$w = 2\,R\,sin\,\tfrac{1}{2}\,F \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

$$\text{But} \quad N = \frac{R}{w} \quad . \quad . \quad . \quad (approx.) \quad . \quad . \quad . \quad (5)$$

$$w = \frac{R}{N} \quad . \quad . \quad . \quad (approx.) \quad . \quad . \quad . \quad (6)$$

From similar triangles we have

$$\tfrac{1}{2}\,w : \tfrac{1}{2}\,G :: R : D$$

$$\text{whence} \quad w = \frac{R\,G}{D} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad : \quad (7)$$

Formulas (2), (5), (6) and (7) may be used as working rules. The results obtained by (2), (5) and (6) are not exact but are of sufficient accuracy for all practical purposes. The error in finding D by formula (2) is $N\,G\,exsec\,\tfrac{1}{2}\,F$. For example, taking $G = 4.71$ ft., the value of D obtained by (2) is .08 ft. too small when $N = 6$; .04 ft. too small when $N = 9$; and .02 ft. too small when $N = 12$. The value of w by (5) is .01 ft. too large when $N = 7$ and $R = 30$ ft., but becomes more exact for larger values of N and R. Formula (7) gives a very simple relation between the important parts, and as it contains neither N nor F, has a more general application than the other working rules.

It is usually more convenient and economical to use standard frogs and alter the stall angle to correspond than to make and keep on hand odd sized frogs, especially where the round house is not a full circle. Table I is of value in this connection, since it give values of D for the common sizes of frogs, and also values of d and w for four sizes of turntables. For any other sizes of turntable d may be found by formula (3), or d and w may be obtained by interpolating between the values given in the table.

TABLE I.—FROG FUNCTIONS FOR FOUR SIZES OF TURNTABLES.

G = 4.708 FEET.

FROG.		DIST.	50 ft. Turntable. R = 25 ft.		55 ft. Turntable. R = 27.5 ft.		60 ft. Turntable. R = 30 ft.		65 ft. Turntable R = 32.5 ft.	
NO.	ANGLE.	D	d	w	d	w	d	w	d	w
4	14° 15′	18.98	—6.02	6.20	—8.52	6.82	—11.02	7.44	—13 52	8.06
4½	12° 40′.8	21.32	—3.68	5 52	—6.18	6 07	— 8.68	6.63	—11.18	7.18
5	11° 25′.3	23.66	—1.34	4.98	—3.84	5.47	— 6.34	5 97	— 8.84	6.47
5½	10° 23′.3	26 00	1.00	4.53	—1.50	4.98	— 4.00	5.43	— 6.50	5.89
6	9° 31′.6	28.34	3.34	4.15	0.84	4.57	— 1.66	4.98	— 4.16	5.40
6½	8° 47′.8	30.70	5.70	3.85	3.20	4.23	0.70	4.62	— 1 80	5.00
7	8° 10′.3	33.04	8.04	3.56	5.54	3.92	3.04	4.27	0.54	4.63
7½	7° 37′.7	35.39	10.39	3.33	7.89	3.66	5.39	3.99	2.89	4.33
8	7° 09′.2	37.74	12.74	3.12	10.24	3.43	7.74	3.74	5.24	4.05
8½	6° 44′	40.09	15.09	2.94	12.59	3.23	10.09	3.52	7.59	3.82
9	6° 21′.6	42 43	17.43	2.77	14.97	3.05	12.43	3.33	9.93	3.61
9½	6° 01′.5	44.79	19.79	2.62	17.29	2.89	14 79	3.15	12.29	3.41
10	5° 43′.5	47.14	22.14	2.50	19.64	2.75	17.14	3.00	14.64	3.25
10½	5° 27′.1	49.50	24.50	2.38	12.00	2.62	19.50	2.85	17.00	3.16
11	5° 12′.3	51.84	26.84	2.27	24 34	2.50	21.84	2 72	19.34	2 95
11½	4° 58′.7	54 21	29.21	2.17	26.71	2.39	24.21	2.61	21.71	2.82
12	4° 46′.3	56.54	31.54	2.08	29.04	2.29	26.54	2.50	24 04	2.71

The special case of the second method, already stated, where the outer edges of flanges of the nearer rails of adjacent tracks are brought in contact on the edge of the pit, is the standard on many roads, and it is undoubtedly the most desirable plan for small-sized round houses.

The following formulas relate to this case.

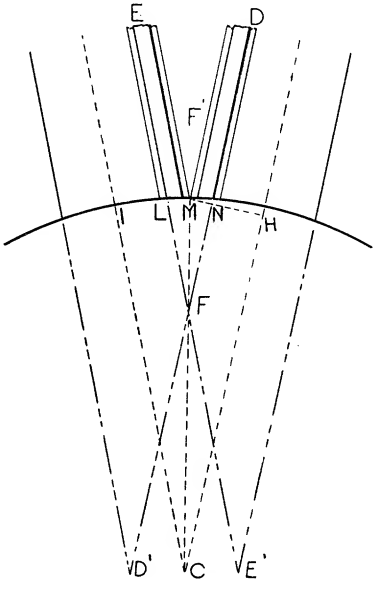


FIG. 2.

In Fig. 2, C is the center of the turntable.

$$C\ M = \text{radius, } R.$$

$$L\ N = b + h$$

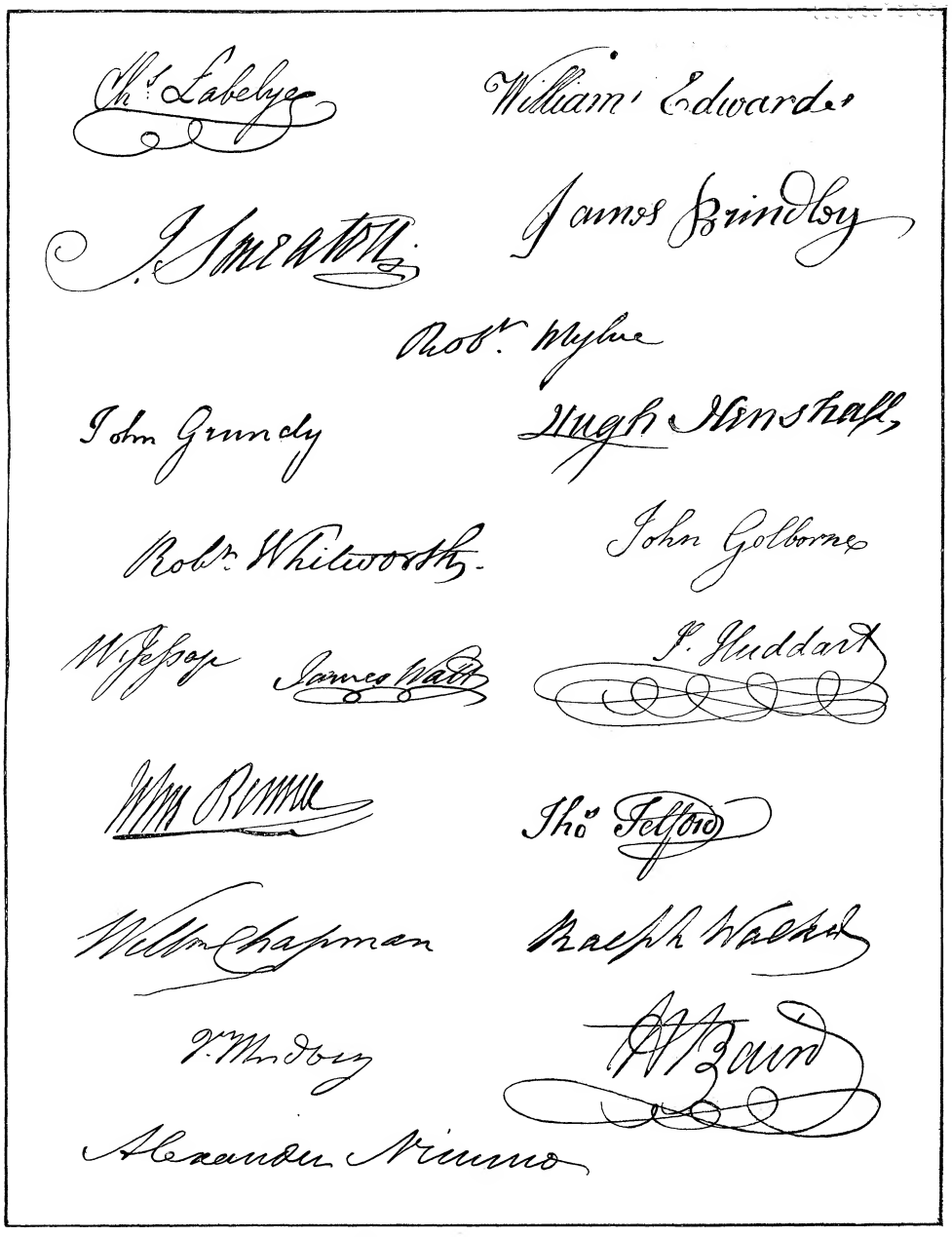
$$N\ H = \tfrac{1}{2}\ G$$

F is the point of intersection of gage lines EE' and DD'.

Now from Fig. 2, we have by trigonometry

$$\sin M\ C\ H = \frac{M\ H}{M\ C}$$

$$\sin \tfrac{1}{2}\ F = \frac{(b + h + G)}{2\ R} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$



SIGNATURES OF EARLY BRITISH ENGINEERS.

FROM VOL. I, TRANS. INST. C. E.

When the rails meet in a point on the rim circle, as in the special case of method (1), we have $M\ N = 0$ and

$$\sin \tfrac{1}{2}\ F = \frac{G}{2R} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

The first line in Table II gives values of the central angle F when the rails meet in a point on the rim circle. The remainder of the table gives values of F for values of $(b+h)$ equal to 5¾, 6, 6¼, 6½, and 6¾ ins. respectively.

TABLE II.—VALUES OF STALL ANGLE FOR THE SPECIAL CASES OF (1) AND (2). G = 4.708 FT.

(b+h)	R=25 ft	R=27 5 ft	R=30 ft	R=32.5 ft.
	F	*F*	*F*	*F*
*	10° 50′	9° 49′	9° 00′	8° 18′
5¾″	11° 54′	10° 49′	9° 55′	9° 09′
6″	11° 57′.5	10° 52′	9° 57′ 5	9° 11′.5
6¼″	12° 00′	10° 54′ 5	10° 00′	9° 14′
6½′	12° 03′	10° 57′	10° 02′	9° 16′
6¾″	12° 06′	11° 00′	10° 04′.7	9° 18′

Some roads have selected a number 7 frog for use in round house layouts because the angle of this frog is such as to give almost exactly 44 stalls in the full circle. Instead of taking a frog whose angle corresponds to one of the numbers given in Table I, some roads have adopted for this purpose a frog whose angle is some aliquot part of 360°. A very convenient frog angle is one of 9°00′, which gives 10 stalls per quadrant or 40 stalls for a full circle. By referring to Table II, however, we see that no frogs are required for a turntable larger than 60 feet when $F' = 9°00'$ and that the rails then meet in a point on the rim circle. For a small round house with a 50 foot turntable, 12°00′ makes a convenient stall angle, and for a 60 foot turntable a 10°00′ stall angle is to be preferred when it is possible to design the round house so that these angles will give the necessary width of stall.

While it is believed by some that no particular care is required to properly lay out a series of round house tracks where frogs are used, there are enough cases which show gross carelessness upon the part of some one to suggest that the engineer should use as much care in this as in any other kind of work in checking his results.

*Special case of (1) where rails meet in a point on the rim circle.

BLUE PRINTING.

By E. I. Cantine, '87.

The "blue print" process of obtaining copies of drawings has become, in this country at least, an invaluable aid to the architect and engineer. On account of its wide and common use, it is thought that a few lines thereon may be of interest and profit.

The principle involved in blue printing is that the chemicals with which the paper is coated, when acted upon by the sunlight are changed into a compound insoluble in water. In the process of blue printing, the dark lines of the tracing (or negative, it may be termed) intercept the sun's rays, and that portion of the sensitized paper beneath these lines remains unchanged. The remaining surface of paper is chemically changed, and when placed in a bath, the chemicals on the unexposed surface are washed away, leaving white lines on a blue background.

This much being plain, it will be readily seen that the lines of the tracing should be as opaque as possible, and the body of paper or cloth transparent; the first to obtain clean white lines, the second to facilitate rapid printing. The best material for negatives is tracing cloth. It comes in rolls of various widths. Tracing paper is supplied in sheets and in rolls. The best grade I have seen is a bank-note tracing paper sold by the Keuffel & Esser Co. The paper is much cheaper than tracing cloth, but not as good, being less durable, and not as convenient to handle. Blue prints may be made from drawings on ordinary book paper. Blue prints can be readily taken from inset sheets such as those issued by Engineering News and other magazines. Prints may be taken from other blue prints, if the original is a good print on a thin or medium thick paper. If it is desired to make a print of a drawing made on a Whatman, Paragon or other thick paper, some device may be necessary to render the paper transparent. For this purpose the following have been recommended. Sprinkle the back side of the paper with paraffine, and pass a hot iron over the surface. The paraffine may be removed with ben-

zine or other solvent of paraffine. Another plan is to coat the paper with a solution of castor oil and alcohol. This solution may be removed by washing the paper with additional alcohol.

To obtain solid opaque lines, India ink gives the best results. Vermillion red or a cadmium yellow is nearly as good. (Use the cake water colors and mix them to a thick consistency. The prepared indellible inks are not as good for this purpose). I should place other water colors in order of opaqueness as follows: Vandyke brown, burnt sienna, raw sienna, gamboge, carmine red, sepia, Paine's grey, green and blue.

Preparation of Paper.

Blue print paper already prepared can be purchased in rolls of commercial width. Where but little printing is to be done, this is probably the most convenient and satisfactory. The paper will keep for several months.

Where a large amount of printing is to be done it is much cheaper to prepare your own paper. You may also sometime find yourself where you can not purchase the prepared article, and have not time to send away for it, while you may be able to purchase the chemicals at the nearest drug store, and the unprepared paper at the newspaper office, if none can be found in the stationery stores. The best paper is one free from chemicals, tough, and of medium thickness. The proper thickness will depend upon use to be made of print. If to be used on work where it is to be handled and thrown around, a thick, tough paper is needed. Dealers in engineers' stationery supplies furnish an excellent grade of paper, "Helios" brand, for this purpose. It comes in rolls of various widths.

The Solution.

The following formula for preparing paper has been used in the Blue Print Room of the University of Illinois for several years. Experiments have been tried of changing the proportions, but the following formula has been accepted as the best.

Solution A { Red prussiate of potash, (potassium ferricyanide), 1 part by weight; water, 6 parts by weight.

Solution B { Citrate of iron and ammonium, 1 part by weight; water, 4 parts by weight.

Solution C { Solution A one part by weight; Solution B one part by weight.

Solution *A* will keep for a long time. Solution *B* should be kept in a dark place, as it is liable to spoil after a week or so if kept in the light. If used after spoiling the prints will have a streaked appearance. Solution *C* is the one with which paper is treated. It should be mixed at time of using. It will not keep.

The water used should be free from iron. It is better not to use any that has been standing in pipes for any length of time. The chemicals may be purchased at most large drug stores. Cost in Champaign, Ill., $1.00 per pound.

The solution may be applied with a sponge, brush, or swab of cotton flannel. Care should be taken to distribute the liquid uniformly over the surface of the paper. The paper may be dipped in the liquid. The preparation of the paper should be done preferably in a dark room. This room may be lighted by gas or the sunlight admitted through a yellow or red glass, which will cut out the actinic rays.

If, as often happens, no dark room is available, paper may be prepared at night by lamplight. After sensitizing the paper, it should be thoroughly dried before using.

Printing.

The time of exposure of a blue print will vary with character of tracing, kind of weather, time of day, etc. No rule can be given. Experience will have to be the guide. With good sunlight and good tracing, a print may be made in one minute, while in cloudy weather it may require several hours.

The addition of oxalic acid to the blue print solution will hasten the printing in cloudy weather. This result was noticed by Mr. F. W. Latimer, of Vancouver, B. C., and his observations were printed in Engineering News of May 23, 1891, p. 486; and were afterwards reprinted in issue of Dec. 15, 1892, p. 569. As most of the members of this society were not subscribers at that time and have not the paper, I will quote from that article.

"During his experiments, he (Mr. F. W. Latimer) also found that an addition of oxalic acid to the ordinary blue print mixture materially lessens the time of exposure. The solutions used were:

"1. Ammonio-citrate of iron, 120 grains; water, 1 fluid ounce, to which is added a few drops of strong ammonia solution till the odor is quite perceptible.

"2. Potassium ferricyanide, 105 grains; water, 1 fluid ounce.

"3. Saturated solution of oxalic acid.

"For convenience of reference, call a mixture of equal portions of (1) and (2) solution *a*. Call 10 ounces of *a* and 1 ounce of (3) solution *b;* and 10 ounces of *a* and 2 ounces of (3) solution *c;* and 10 ounces of *a* and 3 ounces of (3) solution *d*.

"The relative rapidity of paper coated with these solutions is, in very dull light, approximately as 1:2½:5:10. Solution *d* is thus about ten times as rapid printing as *a* in the light mentioned. For example, a print was made from a tracing on linen in 35 minutes on Feb. 25, 11:30 a. m., on *d* paper during a snow storm, the light being quite dull; while ordinary paper takes the greater part of a day in an equal light. This great difference holds good only in dark cloudy weather; in direct sunlight, *d* paper is only three or four times as rapid as *a*. An explanation of this probably is that a weak light that will reduce the oxalic acid mixture (partly ferric oxalate) has but a faint action on the ferric citrate; while with a strong light both are acted upon at once. For all ordinary purposes it is best not to use more than 20% of the oxalic acid, *i. e.*, the *c* solution, as it is difficult to get the lines to wash white with a higher percentage, even with thick black lines on the negative.

"Ferric-oxalate and potassium ferricyanide mixed makes a very rapid printing paper, and can be made considerably cheaper than paper prepared with ferric citrate; but is too sensitive for ordinary work, and requires more care than can be given it in engineering work, as a rule. Ferric chloride is also more rapid and cheaper, but has the same disadvantages. They seem also to wash off the paper more than the citrate, though a different sizing of the paper might remedy this."

WASHING.

After prints are exposed they should be thoroughly washed in clear water. They should not remain too long in the bath. If on account of impure chemicals or lack of thorough washing the prints have a streaky appearance, it may be well to pass them through a dilute solution of hydrochloric acid. This will also heighten the blue color, making a very strong contrast between the white and blue. Oxalic acid is also said to be good for this purpose.

Blue Print Frames.

Fig. 1 shows a cheap frame easily made. There is nothing new or original about it, but it will give an idea which may be useful when you are in camp in the mountains and suddenly have a blue print job on your hands and no conveniences for doing the work. The frame *A* is made out of 1x4 inch lumber. On the bottom of it is fastened strip *B* upon which rests the glass. On this is placed a cover *C* made of inch boards, well padded on the back with a blanket, flannel or otherwise. This cover is held in the frame and tightened by the pieces *D* which fit into the wedge-shaped notches *E* in the frame. The pieces *D* are fastened to the cover *C* by screws *S*. For a small frame a single strength glass is sufficient. For 24 inches by 30 inches, a double strength glass should be used.

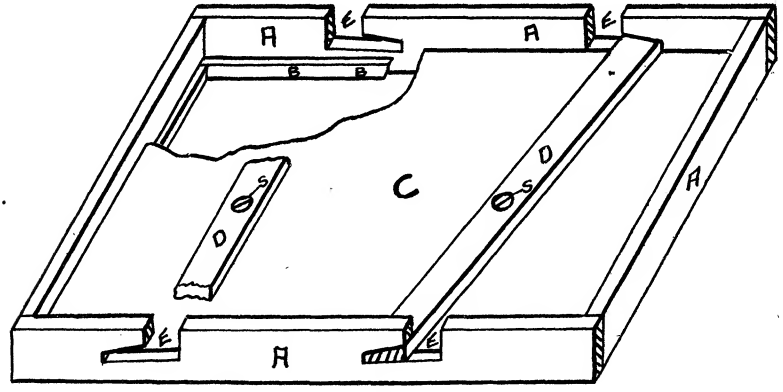


Fig. 1.

For a convenient makeshift, use a drawing board padded for the occasion, upon which place paper and negative, and then cover it with a section of plate glass. Plate glass is heavy enough to take out all wrinkles in the tracing. This plan answers the purpose admirably.

More elaborate blue print frames consist of a plate of glass attached to suitable pulleys to remove it from its bed upon which is placed the printing paper. The entire frame is arranged on wheels and runs out on a track for exposure. For plans and details of such, see Engineering News, Feb. 19th, 1887, p. 119.

With most frames, long prints, say 20 to 30 feet, can not be made without splicing the print. An unique and successful

device for making such prints is used in the Engineer's office of the Northern Pacific Railroad at Tacoma, Wash. It consists of a cylinder about 30 inches in diameter and 12 feet long, upon which is spirally wound first the prepared paper, and then the tracing or negative. The cylinder is turned by hand at a uniform rate of speed, giving a uniform exposure. The paper and tracing are fastened down with thumb tacks. The only objection to this arrangement is that the tracing may not always be tight, resulting in a blurred print. Prints have been made 30 feet long, and longer may be taken if desired. This is especially valuable in making prints of profiles, right-of-way maps, etc., in railroad work.

A long thin board sprung to an arc of a circle, after tracing and paper are attached, has been suggested and used by some. The account of this plan was published in Engineering News, but I have not the reference nor do I remember who suggested it.

THE READJUSTMENT OF LONG RAILROAD TANGENTS.

By Wm. D. Pence, Assistant Professor of Civil Engineering.

It is a well known fact that few railroad tangets of extraordinary length, and, as a rule, of moderate length as well, are in reality right lines; or, to state it more precisely, their horizontal projections are not right lines. The various causes leading to deviations from the true tangent are more or less familiar to all engineers, and it will suffice to refer to the more important of them without attempting an extended discussion. In general the deflections in a railroad tangent are traceable to one or more of the following elements: (1) errors in the manipulation of the transit in the original survey, the most frequent and also the most serious instance of which occurs when in prolonging the line by reversal, the transitman fails to take double sightings; (2) discrepancies in the original track centers owing to instrumental errors or those resulting from the use of disturbed reference points, or perhaps, to the fudging required to make the

track bisect a bridge or an embankment constructed to one side of the true line; (3) failure to lay track to true centers; and (4) shift in center line by repairs. To this list may be added "atmospheric condition" as regards its influence upon the accuracy of the survey. Although the last named element is of little or no importance in cool or cloudy weather, there is no doubt that sensible errors may and do result from attempts to take long sights under the extreme influence of the solar heat. Since this condition is usually more aggravated along railroad track than in the adjacent open country, its influence is found to be considerably greater in the case of resurveys along the track than in location or other surveys made before construction. Notwithstanding this fact, appreciable errors, due to atmospheric influences alone, undoubtedly occur in the latter class of surveys, owing to the long sights occasioned by the usual rush in such surveys. Under the extreme atmospheric conditions of the Gulf Coast country, where the above mentioned influences are frequently magnified by excessive humidity, the writer has been compelled to adopt special methods of survey in order to secure satisfactory results. In the above mentioned locality an ordinary flag pole at a distance of 1,000 feet, when viewed through the telescope of an engineer's transit in the middle portion of a hot day, presents a blurred image apparently several inches in width, and with a sight of one-half that length it is often found impracticable to secure a distinct and stationary image. For this reason a suspension in the alinement survey for a few hours during the middle of the hotter days, similar to that required in careful geodetic work, is found necessary in order to secure satisfactory results. In resurveys made for the purpose of readjusting both grades and alinement, such as are usual with extensive ballasting operations, this midday interval may be utilized in running the levels, since satisfactory results may generally be reached by reducing the maximum length of sight to 250 feet, at which distance reliable readings to hundredths of a foot may, as a rule, be taken with a self-reading rod.

Under the extreme conditions above described, the writer has had occasion to develop a system for the resurvey of long tangent lines, which, with proper modifications to suit local requirements, has proven generally satisfactory. It should be stated in giving a brief description of the system just referred to, that no

special claim of priority is made, since many others have doubtless used an equivalent plan for accomplishing the same result. Before proceeding to a presentation of the matter, a word may properly be said concerning the devices which are available to the engineer for the concealment of lateral deflections in tangent lines in process of readjustment. At first thought the simplest plan would seem to be to make such widening of roadbed or shifting of bridges or other track structures as may be required to permit the restoration of a supposed perfect tangent in the original location; and indeed, where extensive work perhaps amounting to reconstruction is in progress, there may often be no reason why a true tangent should not be established, particularly when the deviations are slight, or when distinct summits at which deflections are most effectually concealed do not exist. Except in such cases, however, the means available to the engineer do not usually admit of extensive lateral shiftings merely for the above purpose, since the operating value of a true tangent is of course no greater than that of a line containing visible lateral deflections.

In the case of tangents of unusual length which were run in with a poorly collimated or manipulated transit in the location survey, a resurvey often develops the fact that the supposed tangent is in reality an exceedingly flat curve or a succession of such curves in reversed directions, none of them, perhaps, being distinctly visible to even a close observer. Where such curvature exists in a marked degree, it may be thought best to concentrate the deflections into distinct swings at intervals of several miles, but as this usually means little short of reconstruction of a considerable stretch of roadbed, besides giving very unsightly results, the plan is rarely adopted. It has been asserted that attempts at the precise adjustment of track alinement are a sheer waste of time and money, but unquestionably there are occasions when the engineer is open to just criticism if he fails to attend to the finer points of this problem. In the opinion of the writer, the best plan is that in which a careful resurvey of the existing center line of the so-called tangent serves as a basis for the readjustment, the ruling points and rates of deflection being determined in a manner very similar to that used in fixing grade lines. Such a system will now be described.

The track is carefully chained with a 100-foot steel tape, the measurement being made preferably along the tie ends, say 3 or 4 inches to the right of the right hand rail. Eleven chaining pins are used, and instead of indicating the stations by means of stakes, an arrow mark made with white lead on the rail flange opposite the pin is used for this purpose. The number of the station is marked on the rail flange to the right of the arrow, a small pot of white lead and a suitable brush being carried for the purpose. This plan of marking the station on the rail flange has much to commend it, and it should be stated that when properly applied the white lead may be distinguished after a couple of years, unless covered over by oil and dirt. The chaining party thus need not consist of more than three persons, viz.: the front and rear chainmen and the engineer, or a competent assistant who does the marking and records the station numbers of all bridges, road crossings and other track structures, summits when distinct enough to assist in the readjustment, and, in fact, all important features along the line.

Reference has already been made to the use of the midday hours in the leveling operations through a reduction in the length of sight. The adoption of a 250-foot maximum sight under the extreme atmospheric conditions above described led to the use of a special plan in the leveling work, which was found to largely compensate for the loss of time resulting from the shorter sights. This plan consisted in driving a solid bench stake in a secure place at each tenth station. The convenience in the subsequent work of setting ballast grades, as well as the constant checking of levels by means of these bench marks, proved the system to be an excellent one.

The transit party consists of a transitman, a rear flagman and a front flagman, the last named being provided with a flag pole, tacks, pocket tape, hand axe, and a stout shoulder sack containing a supply of hard wood hubs. Commencing at one end of the tangent line, (which will be called station 0 for the sake of simplicity), a hub is driven midway in the space between two ties, where it will be least apt to be disturbed. After setting a tack in this hub to agree with the existing track center, this point is carefully referenced out. This operation is repeated at stations 10 and 20, except that the referencing may perhaps be omitted, provided the track foreman's attention is called to the

stakes so as to avoid disturbing them in the repairs. Now with the rear flag on the hub at station 0 and the transit accurately set over the hub at station 10, double sights are taken to the front flag at station 20, the two sightings being fixed by tacks set in the edge of the tie adjacent to the space in which the hub is located (usually within 8 or 10 inches of it). After repeating the sights as a check, the transitman passes to station 20 as rapidly as possible, the removal of the transit being the signal to the two flagmen to move forward ten stations. Upon reaching station 20, the transitman bisects the space between the two tacks just sighted in, and also carefully marks the existing track center on the same tie edge. He then measures to the nearest hundredth of a foot the distance that the existing center is to the right or to the left of the mean point and records the same in the manner to be described. Now setting the transit *over the center hub* at station 20, and with back sight at rear flag *on hub* at station 10, the double tacks are set on tie edge at station 30, adjacent to the center hub, which the front flagman has in the meantime established at the latter station. The party moves forward ten stations, the bisection and measurement at 30 is made by the transitman as above described, and the work thus proceeds indefinitely, the full ten stations being taken as a fixed length of sight, and the back sight being taken on the previous hub. The front flagman is supplied with a memorandum of important bridges and summits or other local features which may act as ruling points in the readjustment, and upon reaching the designated object (generally indicated in the memorandum by the nearest even station) a hub is set and the double tacks are fixed in the adjacent tie edge, after which the front flagman proceeds to the even tenth station as before. In moving forward the transitman stops at the intermediate point and goes through the process already described, except that the transit is not set up at intermediates.

The form of keeping the notes and also the method of reducing and applying them in the readjustment of the line are indicated in Table I, and the "lateral profile" shown in Fig. 1 was made from these notes. This "profile" was originally constructed on Plate "A" profile paper, taking 2,000 feet per inch longitudinally, and 0.40 feet per inch laterally, which scales are convenient for ordinary cases. Columns II and III in Table I contain

TABLE I.

Field Notes and Data for Use in the Readjustment of a Long Tangent.

Station.	Old Line. Deflections. −L	Old Line. Deflections. +R.	Old Line. Partial ±	Old Line. Total. R.	Readjusted Line. Rate. ±	Readjusted Line. Total. R.	Readjusted Line. Shift. −L.	Readjusted Line. Shift. +R.	Remarks.
I	II	III	IV	V	VI	VII	VIII	IX	X
0			0.00	10 00		10.00	0.00		Totals are taken with reference to a vertical plane 10.0 ft to the left of and parallel to the line 0—10.
10			0 00	10.00		9.98	0.02		
20		+0.05	+0.05	10.05		9 96	0.09		
30	−0.06		−0.01	10.04		9.94	0.10		
(36)		(+0.08)	(+0.07)	(10 11)		(9.93)	(0.18)		Bridge No. 341, 42 ft. long.
40		+0.10	+0.09	10.13		9.92	0 21		
50	−0 08		+0.01	10.14		9.90	0.24		
60	−0.10		−0.09	10.05		9.88	0.17		
70	−0.04		−0.13	9.92		9.86	0.06		
80	0.00		−0.13	9.79		9.84		0.05	
(82)		(+0.06)	(+0.03)	(9.82)		(9 83)		0.01	Bridge No. 342, 70 ft. long.
90		+0.11	−0.02	9.77		9.82		0.05	
100		+0.05	+0.03	9.80		9.80	0 00		
110		+0.02	+0.05	9.85		9.78	0.07		
120	−0.01		+0.04	9.89		9.76	0.13		
(125)	(−0.13)		(−0.11)	(9.78)		(9.75)	(0.03)		Well-defined Summit.
130	−0.18		−0.14	9.75		9.71	0.04		
140		+0.05	−0.09	9.66		9.63	0.03		
150	0.00		−0 09	9.57		9.55	0.02		
160	−0.05		−0.14	9.43		9.47		0.04	
170		+0 09	−0.05	9.38		9.39		0.01	
180	−0 03		−0.08	9.30		9.31		0.01	
190		+0.02	−0.06	9.24		9.23	0 01		
200	−0.05		−0.11	9.13		9.15		0.02	Summit.
	−0.60	+0.49	−0 87						

−0 02 per 1000′ (rate, 0 to 125)

−0 08 per 1000′ (rate, 125 to 200)

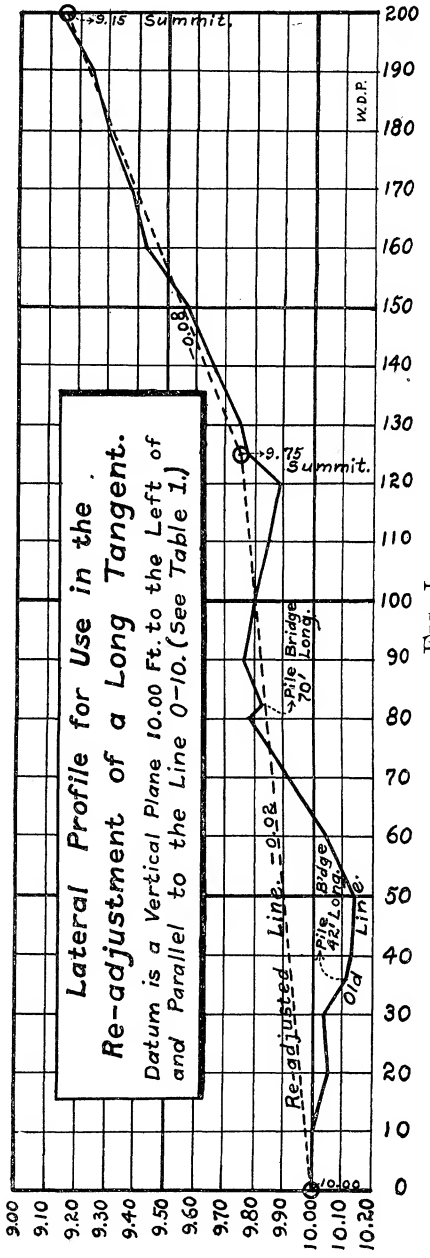

Lateral Profile for Use in the Re-adjustment of a Long Tangent.
Datum is a Vertical Plane 10.00 Ft. to the Left of and Parallel to the Line 0-10. (See Table 1.)
9.15 Summit.
9.75 Summit.
W.D.P.
0.08
0.02
Re-adjusted Line.
Old Line.
Pile Bridge 421' Long.
Pile Bridge 70' Long.
10.00
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
9.00
9.10
9.20
9.30
9.40
9.50
9.60
9.70
9.80
9.90
10.00
10.10
10.20

FIG. I.

the deflections measured in the field in the manner above described, the fractional stations and the corresponding notes being enclosed in parentheses. Column IV contains the continued sum of the deflections recorded in II and III, the results being in reality the rates of inclination of the corresponding back sights to the datum plane. Considering this fact, the method by which the fractional "partials" are obtained is easily seen. Column V contains the totals with reference to a vertical plane 10.00 feet to the left of and parallel to the line 0-10 and corresponds to the "elevation" column in the common system of level note keeping. The datum plane is thus assumed to one side in order to avoid totals of opposite signs. The process of making the readjustment to agree with the ruling points, given in columns VI to IX inclusive, is essentially the same as that of laying grade lines and, being clearly shown in Fig. 1, no description seems necessary. The notes may be checked in a manner similar to that used in level notes. Thus the algebraic sum of Columns II and III (omitting intermediates) should be equal to the "partial" for station 200 given in Column IV, and the algebraic sum of Column IV should be equal numerically to the difference between the first and last totals of Column V.

An examination of the method of working up the totals will show that the results are practically the same as would be obtained by prolonging the datum line indefinitely and measuring the deflections direct, the approximation usually being so slight as to require no consideration. In the case of a tangent deflecting continuously in one direction to an extreme degree, it may be advisable ultimately to assume a new datum plane. With broken or rolling country it will generally be impracticable to use the uniform length of sight as above described, but modifications of an obvious character may be made without affecting the efficiency of the system.

If it is desired to record the angular deflections in the tangent, it is sufficient to use the value of one second of arc, .000005 (more exactly .0000048) which is easily remembered as "five naughts and a five"; or one minute of arc, .0003 (more exactly .00029) which can be remembered as "three naughts and a three." It is thus seen for example, that 0.01 feet subtends an angle of 2 seconds at a distance of 1000 feet.

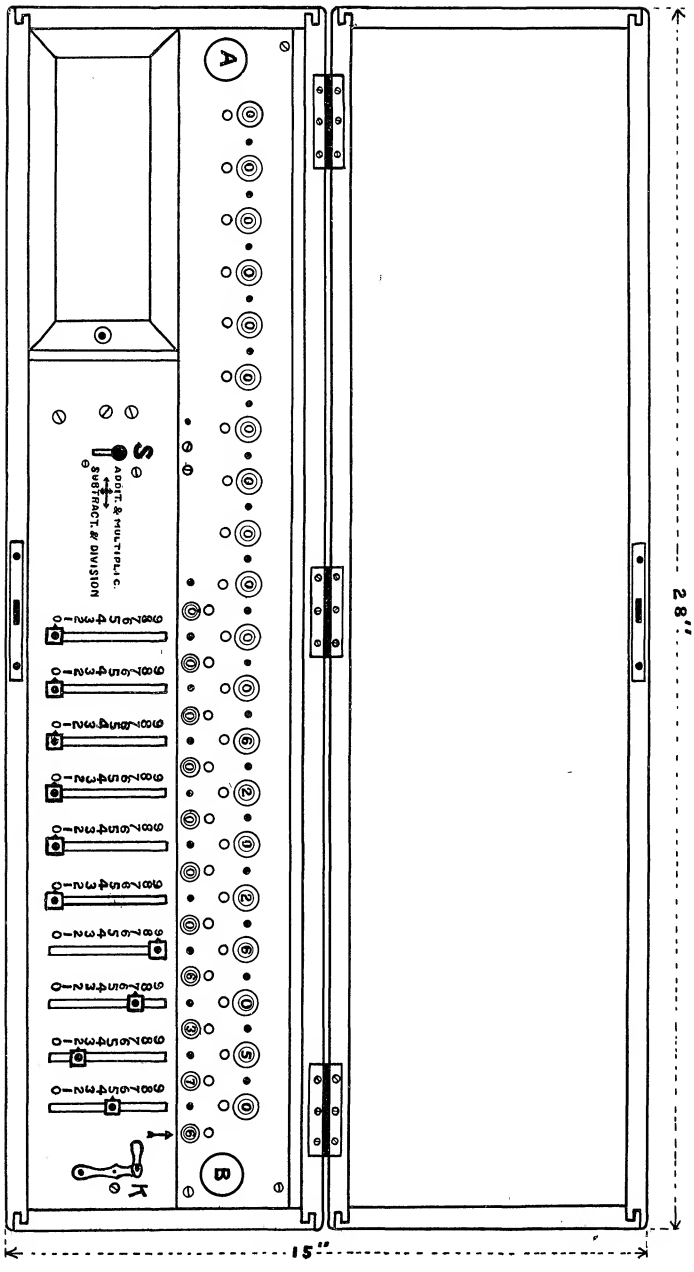
THE THOMAS COMPUTING MACHINE.

By O. E Strehlow, '94.

Strange to say, few American engineers are acquainted with the "The Thomas Computing Machine," which is manufactured in Europe, and which has been in use there for twenty years. In this machine unfailing accuracy, surprising rapidity of operation, ease of manipulation, and minimum possibility of making blunders, go hand in hand. To work a problem a few manual touches and shiftings are all that is necessary.

The machine is composed of two main parts, the key-plate and the figure-slide (see Fig. 1, page 38). The key-plate (the lower or front part) is fixed in a mahogany case, and contains the interior shifting mechanism which it covers. The figure-slide (the upper or back part) is movable both from side to side between the key plate and the back of the case, as well as round its axle-rod; *i. e.*, up and down in a manner to give it a slanting position. These two parts in their proper position on a level with each other, form the so-called external working surface, and present the figures, stops, grooves, handles, knobs, etc., by means of which all the different kinds of calculation are effected.

The key-plate presents at the front right-hand corner the handle, marked **K**, which when properly turned sets the whole mechanism in motion. The successive turns of the handle are indicated by the number appearing opposite the arrow in the lower row of holes in the slide. To the left of the handle the key-plate is slit by a series of grooves (10 in number); to the right of each groove there is a series of numbers from 0 to 9 (see Fig. 1, p. 38). Projecting buttons move up or down these grooves and may be stopped opposite any figure. In using a slide rule it is necessary to exercise care to cause a certain division on the slide to be coincident with, or a certain distance from, a particular division on the scale. Such care need not be taken in placing the projecting buttons opposite certain figures on this machine, since a projection on the lower side of the button engages in a


A
B
S
ADDIT. & MULTIPLI C.
SUBTRACT. & DIVISION
K
28"
15"

depression, which insures that the button will come exactly opposite a particular figure when the button is placed in an approximate position. Still further to the left of the grooves is the steering-knob, **S**, likewise movable within a groove. When *pushed up* this knob indicates the mechanism to be in position for either addition or multiplication, as shown above the arrow beside it; and when *below* the arrow the machine is set for subtraction or division.

The method of using the machine is best understood from an illustration of the solution of an example, say in multiplication, viz: $9725 \times 6376 = ?$. The multiplicand is to be set off in the key-plate grooves. The figure 5 will find its place in the first or right-hand groove, and the other digits in order from right to left. The figures of the multiplier, 6376, are then turned off successively by means of the handle, beginning at the right; *i.e.*, the multiplicand, 9725, is first multiplied by 6, (the unit figure), which is accomplished by turning the handle six times; next the multiplicand is multiplied by 70, (7×10), which is done by moving the figure-slide one space to the right and then giving the handle 7 turns. In the same way, in order to multiply by 300, (3×100), the figure slide is moved another space to the right and the handle is turned 3 times; and finally, to multiply by 6000, (6×1000), the slide is moved another space to the right and the handle is turned 6 times, which completes the operation. The required product, which equals the sum of the four products just mentioned, appears in the top row of the slide (see Fig. 1, p. 38), while the multiplier appears in the lower holes of the slide and the multiplicand still appears on the key plate as originally set off.

To find the quotient of two numbers, the steering-knob, **S**, is made to point to the words "Subtract. and Division," Fig. 1, p. 38, as mentioned before. The rest of the work is the reverse of multiplication.

The method of extracting square root with the machine is interesting and is worthy of mention. It might properly be celled the extraction of square root by subtraction. The principle will first be illustrated without the use of the machine, by the following simple example: $\sqrt{5329} = ?$. Having pointed off in the usual way, thus, 53 29, proceed to subtract 1 from the left

portion of the power, or what is the same thing, 1 00 from the whole number, which gives 52 29 for the difference; subtract 3 00 from this difference, 5 00 from the next difference and so on, subtracting the successive odd numbers until the difference becomes smaller than the subtrahend. This particular example requires 7 such subtractions; when the difference will be 4 29 and the subtrahend 13 00. The first figure in the required root will then be 7, since seven differences were subtracted. To find the other figure of the root, 4 29 is taken as the new minuend and 1 41, ($\{2\times7\times10\}+1$),* as the subtrahend; their difference is 2 88 which is used for the second minuend; the second subtrahend being 1 43, (1 41+2), gives 1 45 for the second difference. The next subtrahend will be 1 45, (1 43+2), and since the difference is now zero the solution is completed. The other figure of the root is 3, since in the latter part of the solution three subtractions were made. Therefore $\sqrt{5329} = 73$.

To extract square root by the machine, we proceed as follows: The given power is set down in the top row of the slide. The square root of the number is made to appear in the lower row of the slide in the following manner. Problem, $\sqrt{2209} = ?$. Set the machine thus:

In the top row of the slide 22 09
In the first and second groove 1 00

Then proceed to find the square of the first two figures, 22. To do this give one turn, raise the setting in the key-plate grooves by two units, *i. e.* from 1 to 3; turn again, then raise the setting from 3 to 5, and so forth. Always raise the groove setting by two units after each turn, till the sum in the top row of the slide is reduced below the one in the key-plate. The appearance of the surface will successively present the following phases:

Original setting on top row is 22 09 and on lower row 0
First setting on key-plate is 1 00
One revolution gives on top row 21 09 and on lower row 1
Second setting on key-plate is 3 00
One revolution gives on top row 18 09 and on lower row 2
Third setting on key-plate is 5 00
One revolution gives on top row 13 09 and on lower row 3
Fourth setting on key-plate is 7 00
One revolution gives on top row 6 09 and on lower row 4

*The new minuend is obtained by doubling the root already found and annexing 1. The succeeding minuends are obtained by annexing the successive odd numbers to twice the root already found.

The last sum turned up, 6 09, being smaller than the key-plate reading, 7 00, the 4 turned up in the lower row is the first part of the root of 22. Further turning in this position being infeasible, shift the slide one space to the left. The key-plate setting will then become 81, ($\{2\times4\times10\}+1$)*. The remainder of the solution is performed in the same way as before. The successive operations are as follows:

Previous setting on top row is.	6 09	
First setting on key-plate is	81	
One revolution gives on top row	5 28	and on lower row 41
Second setting on key-plate is	83	
One revolution gives the top row	4 45	and on lower row 42
Third setting on key-plate is.	85	
One revolution gives on top row	3 60	and on lower row 43
Fourth setting on key-plate is	87	
One revolution gives the top row	2 73	and on lower row 44
Fifth setting on key-plate is	89	
One revolution gives on top row	1 84	and on lower row 45
Sixth setting on key-place is	91	
One revolution gives on top row	93	and on lower row 46
Seventh setting on key-plate is	93	
One revolution gives on top row	00	and on lower row 47

The difference being zero, the calculation is done, and the 47 in the lower row is the square root of 2209.

By the help of the "Thomas Computing Machine," every arithmetical problem, from the simplest work in addition, to the most intricate calculation, can be solved with surprising rapidity. The writer added a column of ten numbers, each consisting of ten digits, in a little over two minutes, with this machine without having had any previous practice in adding with it. A week's practice would reduce the time of working this problem to one and one-half minutes, or less.

Where the most extensive table of logarithms fails to give the accuracy required in fine work, the "Thomas Computing Machine" gives an absolutely correct result, provided this result contains less than twenty-one digits. There is little chance of having a larger number than one consisting of twenty digits. The machine is also made in two smaller sizes, the smallest allowing twelve digits as the maximum in the answer. The machine in

*See foot note, page 40.

use at the University of Illinois is of the largest size, and was obtained from Europe through the Keuffel & Esser Co., New York. The cost of the different sizes is about $125, $185, and $225.

Another advantage which this machine possesses is that the tiresome mental labor of ordinary calculation is reduced to the simple jotting down of the results obtained, either by the person at the machine or, better still, by a second person. The instrument attains its highest qualities in time-saving when two persons divide the work between them, thus giving a counter check upon one another. One person should read the problems and take down the answers, while a second should be employed to do the grinding.

The real work of operation is done by manual touches and shiftings, easily acquired within a few hours. A couple of day's practice will enable any man of ordinary capacity to fully master this unparalelled invention.

After the method of operating the machine has been learned, it is clear that there is no more strain on the mind of the computer than upon the mind of the street-car conductor when he tallies the fares on his register.

Another strong point for the "Thomas Computing Machine" is that the possibility of making blunders is reduced to a minimum. For instance, in division the divisor may erroneously be taken for the dividend. In this case the computer's attention is called to the blunder by the ringing of a small bell inside the instrument. As soon as the computer is again on the right track the bell rings a second time to inform him that all is well. The writer is of the opinion that others as well as himself would like to have in their possession a little bell that would ring automatically whenever a mistake is made.

METHODS OF HANDLING FREIGHT.

By A. M. Munn, '95.

Few persons not connected with the freight department of a railroad understand the methods which are used in handling large quantities of freight at terminal or transfer points. It is comparatively an easy matter to keep account of freight received or delivered in car load lots, but for merchandise the task is more difficult.

In this article freight will be considered as divided into two classes, out-freight and in-freight. The first class includes merchandise received from connecting railroads or boat lines destined to points beyond, as well as shipments originating in the city. The second class will include only shipments delivered to private firms or warehouses within the city.

At Chicago, New York, and other large terminal stations, the business is handled through several warehouses suitable to the service performed. These houses are designated according to the service performed through them, as out-freight house, transfer house, boat house, and in-freight house. The in-freight and out-freight houses are usually located as convenient to the business district as the facilities of the road will allow, in order to reduce drayage charges to a minimum.

The out-freight house is built parallel to the street forty or fifty feet from the sidewalk. It is usually one story high, forty feet wide and several hundred feet long. The floor is paved with wood blocks or plank, and is about three feet higher than the surface of the street. The latter should be paved with brick or other durable material, and should be sloped slightly towards the warehouse. This facilitates backing in heavy drays and saves a great deal of time. On the other side of the house are the side-tracks, laid eleven feet between centres and six feet from the house. On the receiving side doors eight feet wide are placed about sixteen feet apart. On the track side doors ten feet wide are placed about two feet apart. This allows the use

of cars of any length. The cars are set so that the doors of cars on adjacent tracks are opposite, not only to each other, but also to a door of the house. The intervals from house to car and from car to car are bridged with iron aprons. Before every other door on the receiving side is placed a five-ton scale, the platform of which is flush with the floor of the house. The doors are raised vertically by counter-weights. For each door on the receiving side a gang of six or seven men under a check clerk is required.

The question now is how to direct the loading so that all shipments for the same station will be loaded into the same car, although received from a dozen wagons at as many doors. It is done as follows:* All territory reached by the company's own or connecting lines is grouped to suit the traffic and secure economy in train service. Beginning at the initial point, the stations are grouped according to the amount of freight received per day. The groups are numbered consecutively, and stations averaging a car load (10,000 lbs.) of merchandise per day are grouped alone, but no two stations not on the same branch of road are grouped together. At junction points, where there are several connecting lines, each line is given a number provided enough freight is received per day to warrant running a separate car. If not, two or more lines are combined and loaded into one car, a practice which necessitates transferring the load at the junction. Having arranged and numbered the groups, the stations or roads constituting each group are printed on slips of paper, which are posted on small boards bearing the number of the group. There is also prepared a lot of boards, 4x10 inches, one for each group, upon which is painted in large figures the number of the group. Beginning at the lower end of the house the doors are numbered consecutively. Over each door is a row of pegs numbered from left to right, there being as many pegs as side tracks. The tracks are numbered from the house out. Then peg "one" designates track "one," etc.

The cars having been set, a list is furnished the foreman on a form as follows:

*The method here outlined is in use on one of the leading roads entering Chicago, and has proven highly successful.

DOOR NO	LOADING NO.	TRACK 1	LOADING NO.	TRACK 2.	LOADING NO.	TRACK 3	LOADING NO.	TRACK 4.
1	107	9068 B. & M.	66	9006 C.B.& Q.	47	18655 Wab		55000 M. D T.
2	98	17054 C B. & Q.	65	1475 C B.& Q.		1454 B.&O.		42300 L. S.
3								
4								

The foreman having an estimate of the amount of freight on the floor and its destination, and knowing the amount usually received during the day, fills in the column of loading numbers. Copies are then sent to the check clerk, and an assistant takes one copy and hangs the numbered boards as designated. For example, door "one," peg "three," No. 47, would be hung indicating that car on track "three," door "one," is to receive freight for points in group 47. The boards with the printed lists are hung within the car for the use of the stevedores, whose business it is to stow the freight so that it will not be injured in transit and can be quickly and easily unloaded. The first station loaded should be the last unloaded.

A teamster arriving at any door presents his shipping ticket to the check clerk who checks the description, destination, number, and weights of the packages as they are unloaded. He signs the original, returns it to the teamster, and keeps the duplicate. He directs the trucker as to what packages to take, and tells him the loading number, such as 65, for example. The trucker then goes along the house until he finds 65 and leaves the package as indicated. He gets the number and initial on the car and reports back to the check clerk. The number and initial is entered in the upper left hand corner with the clerk's name. This forms the basis of all office records. The duplicates are picked up every thirty minutes and carefully revised for mistakes in loading, prepayment of charges, etc.

The in-freight house is similar in every respect, except that a large cooling room is added for perishable goods, such as butter, fresh meats, etc. However, the system is entirely different. The house is divided into sections by an aisle extending down the center with side aisles to the doors, and the sections are numbered. The freight as it is unloaded is entered in a form

known as the "blind tally," together with the car number and initials and the number of the section in which it was deposited. The "blind tally" is then checked against the expense bills, which are made out from the original way-bills, and overs and shorts are reported direct to the tracing department. The section numbers are entered on the expense bills and the goods are then delivered to consignee upon presentation of receipted bill.

BOTTOMS FOR ELEVATED WATER TANKS.

By Jno. A. Lowry, '94, and Paul Chipman, '94.

Iron tanks on trestle or masonry towers have been used in this country for water service for a number of years. Until recently all such tanks have been constructed with flat bottoms supported by a system of floor beams; but tanks with conical and spherical bottoms have been used with success in Europe for several years, and have recently been introduced into this country.

The object of this paper is the comparison of the different styles of tank bottoms with regard to efficiency, appearance and cost. As between conical and spherical bottoms there is no great difference. Theoretically the spherical bottom does not require as great thickness as the conical; but as the plates are more difficult to shape, being in double curvature, the spherical bottom is more expensive. As this difference in cost, however, is slight, and as the connections are the same in both cases, only the conical and the flat bottoms will be compared. To ascertain the relative cost of the different types, thirty-two designs were made, sixteen for tanks on trestle towers and sixteen for tanks on brick towers. In each case eight of the designs were for conical bottoms and eight for flat bottoms. The diameters chosen were 12, 16, 20, and 25 feet, and with each diameter two heights were used—30 and 60 feet.

The conical bottoms were given a slope of 30° with the hori-

zontal for the reason that at that angle the thickness of the bottom equals the thickness of the lowest plate in the shell. The thickness of the flat bottoms was also made the same as that of the lowest plate of the shell.

The estimates of cost were based on the following prices: Rolled shapes, 3 cents per pound; steel plate in flat bottom, 4 cents; steel plate in conical bottom, 5 cents; steel plate in trestle, 5 cents; built up plate girders, 3½ cents; field rivets, 4 cents each; brick masonry, $8.00 per cubic yard; concrete, $4.50 per cubic yard. The prices on steel cover all expenses, including erection and contractor's profit, except the actual cost of riveting.

The costs given for bottoms include the cost of the bottom and its supports and connections.

TANKS ON TRESTLE TOWERS.

As far as actual water service is concerned, a properly designed tank is as efficient with one kind of bottom as with another, if there be the same capacity and average head in both cases. The flat bottom, however, possesses some advantages in regard to ease of design and simplicity of connections.

While it is largely a matter of individual taste, yet probably all will agree that a tank with a bottom which is a segment of a sphere, or a shallow cone, is more pleasing to the eye than a flat bottom with its system of floor beams. In regard to facility for attachment of exterior ornament, such as balcony or stairway, one style is probably as good as the other, and with such ornament the difference in appearance would probably be slight.

For uniformity the number of posts in the trestle was taken as four in all cases. An increase in the number of posts would probably be favorable to the conical bottom, owing to its peculiar adaptability to a number of points of support.

The flat bottoms are supported by systems of parallel I-beams resting upon two main girders at right angles to them. For conical bottoms branching columns are used, giving twelve points of support.

The costs of the different bottoms are shown graphically in Fig. 1.

These results show that for tanks of ordinary heights and diameters up to 16 or 20 feet, the flat bottom costs less. For low

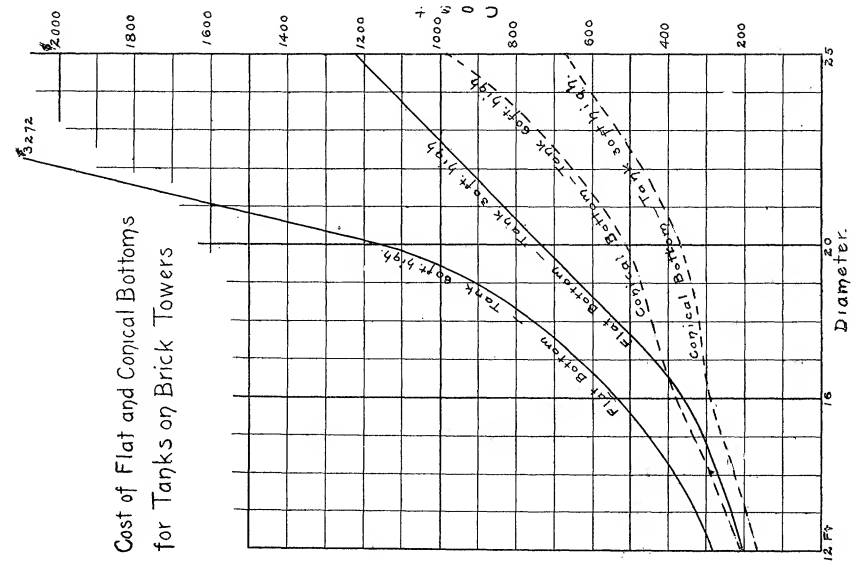

Cost of Flat and Conical Bottoms
for Tanks on Brick Towers
Cost
Diameter
Flat Bottom
Conical Bottom
Tank 30 ft. high
Tank 60 ft. high

FIG. 2.

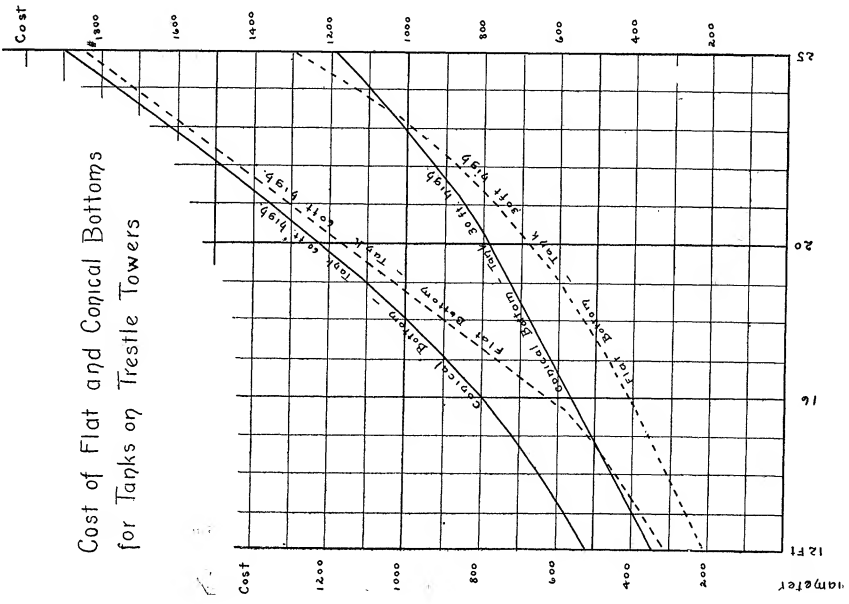

Cost of Flat and Conical Bottoms
for Tanks on Trestle Towers
Cost
Diameter
Conical Bottoms
Flat Bottom
Tank 30 ft. high
Tank 60 ft. high

FIG. 1.

tanks of large diameters the conical bottom is the cheaper. For other sizes there is no great difference in cost.

TANKS ON BRICK TOWERS.

The supports and connections are simpler of design and easier of construction for tanks with conical bottoms than for tanks with flat bottoms. As the bottom and floor system are hidden from view, the style of bottom makes no difference in the appearance. The flat bottoms are supported on systems of parallel I-beams which rest upon an 8-inch stone coping. The conical bottom is attached to the lowest ring of the shell at such a height as to give sufficient clearance of the wall, and to the lower edge of the ring are riveted one or more angles which rest directly on the stone coping.

The difficulty in designing a floor system for a flat bottom is to distribute the pressure over the top of the tower. To the additional masonry required to give the necessary bearing surface is due the rapid increase in cost of flat-bottomed tanks, with increase of size. For the larger tanks the space on top of the wall, between the floor beams, is filled with concrete.

The costs of the different bottoms are shown graphically in Fig. 2. These results show that in all cases the tanks with conical bottoms are cheaper, and that the cost of flat bottoms increases much more rapidly with the size than does the cost of conical bottoms.

LAST WORDS TO THE CIVIL ENGINEERING SENIORS.

By Ira O. Baker, Professor of Civil Engineering.

When the program committee asked me if I would present something here this morning, I immediately thought that perhaps I might use the opportunity for a few final words with our graduating members. Frequently the circumstances and conditions under which anything is said gives it an attention and weight which it would not otherwise have.

When the traveler through an unknown country comes to the brow of a hill, if he is wise he surveys the landscape, selects an objective point ahead, decides upon his path through the valley below, and then proceeds step by step to find his way down the hill through the valley and up on the other side. Obviously the time to decide upon the path through the valley is when we are upon the hill top, and we are more sure to reach the goal by the shortest route if we keep our eye steadily fixed upon our mark ahead.

You are upon a hill top this morning. You are shortly to break off old relations and enter upon new ones. Let us see if we can find a worthy objective point ahead, which shall serve as a help and inspiration while you wend your way through the valley.

I am fully aware that this is the last time that I shall ever address you in the relations of teacher and taught, and it is with mixed feelings of regret and pleasure, of solicitude and anticipation that I bid you adieu, and I fain would reveal to you some of the feeling that a teacher has when he sends his boys out into the world to test their powers—and his. But the occasion demands a higher motive than merely personal pleasure, so I ask your kind indulgence while I try to teach one more lesson. I make this attempt knowing that the occasion and your thoughts will more clearly reveal to you the truth I wish to teach than can my words.

It is not necessary to remind you that recitations are ended, but I do want to urge upon you that you do not cease to be a

student. Whatever the kind and stress of your occupation, keep a little time for study and reading. If your work here has been well done, you have barely reached that point where you are able to gain knowledge by self-directed effort. You will doubtless have many painful illustrations that you do not know it all, but your daily work will compel study of the practical details of your business. You will be compelled to get these matters or you will not get work. I expect you to succeed reasonably well in these particulars, but I desire to urge upon you that you continue to grow, to expand, to increase your powers. You ought always to have in hand some subject upon which you are doing thoroughly downright hard study. Such a course is absolutely necessary for intellectual vigor and activity. In the next few years you ought to study professional subjects as a matter of course, but you ought also to broaden your education and extend your horizon by the study of scientific and literary and historical subjects. I have time only to assert this point, not to prove it.

Undoubtedly you will be tempted to say that you haven't time for such study, but I say you must make the time. If I had time I should like to illustrate this by giving you some of the particulars of the life of Gladstone, and Garfield, and Lincoln, whose labors and cares were simply prodigious, and yet they found time for an astonishingly wide range of reading and study. To make this matter definite, let me urge that you regularly and conscientiously give one half hour each day to the study of some subject which will broaden your knowledge and extend your horizon.

The world moves. New problems are continually arising which must be solved. The state and country has been very liberal to you, and has a right to demand that you shall meet these new obligations when they arise. She expects you to find new and better solutions to old problems, and to lead us into unexplored and undiscovered fields. She has given you five talents. Will you lay them away in a napkin, or will you use them and gain five other talents?

By all means do not fail to cultivate the ability to write and speak your mother tongue correctly, forcibly, and even elegantly. Even an engineer has frequent use for this power, and his ability as an engineer is continually being judged by his written and spoken language. Eads is not infrequently ranked as the lead-

ing American engineer, but his reputation as an engineer is due as much to his ability in writing and speaking as to his knowledge of engineering.

One precaution. Do not become a man of books to the exclusion of affairs. Society is all the time struggling with industrial questions, social reforms, and political problems which you, having received your education as a gift from the state, should help to solve. I have only time to hint this.

In one respect your free education is liable to do you harm. You have received information more cheaply in the past than you ever can in the future. Do not be afraid to spend your money in travel to see things and men. There is a wonderful stimulus in whetting against other men, particularly those engaged in the same business as yourself. Do not fail to use travel as a means of continuing your education. Remember that there is a scattering abroad that increaseth and a withholding that impoverisheth.

Allow me to offer a few hints to guide you in your intercourse with your professional associates.

1. Be patient and don't try to get on too fast. You may be overestimating your own abilities. It takes all summer to ripen the best apples.

2. Be liberal in the measure of your work. Don't even think of excusing yourself from doing what you reasonably can, by saying that you are doing as much as you are paid for. As long as you hold the position and accept the pay, do good, honest, faithful work. If the labor demanded is too great, make a courteous, frank, straightforward protest, or offer your resignation.

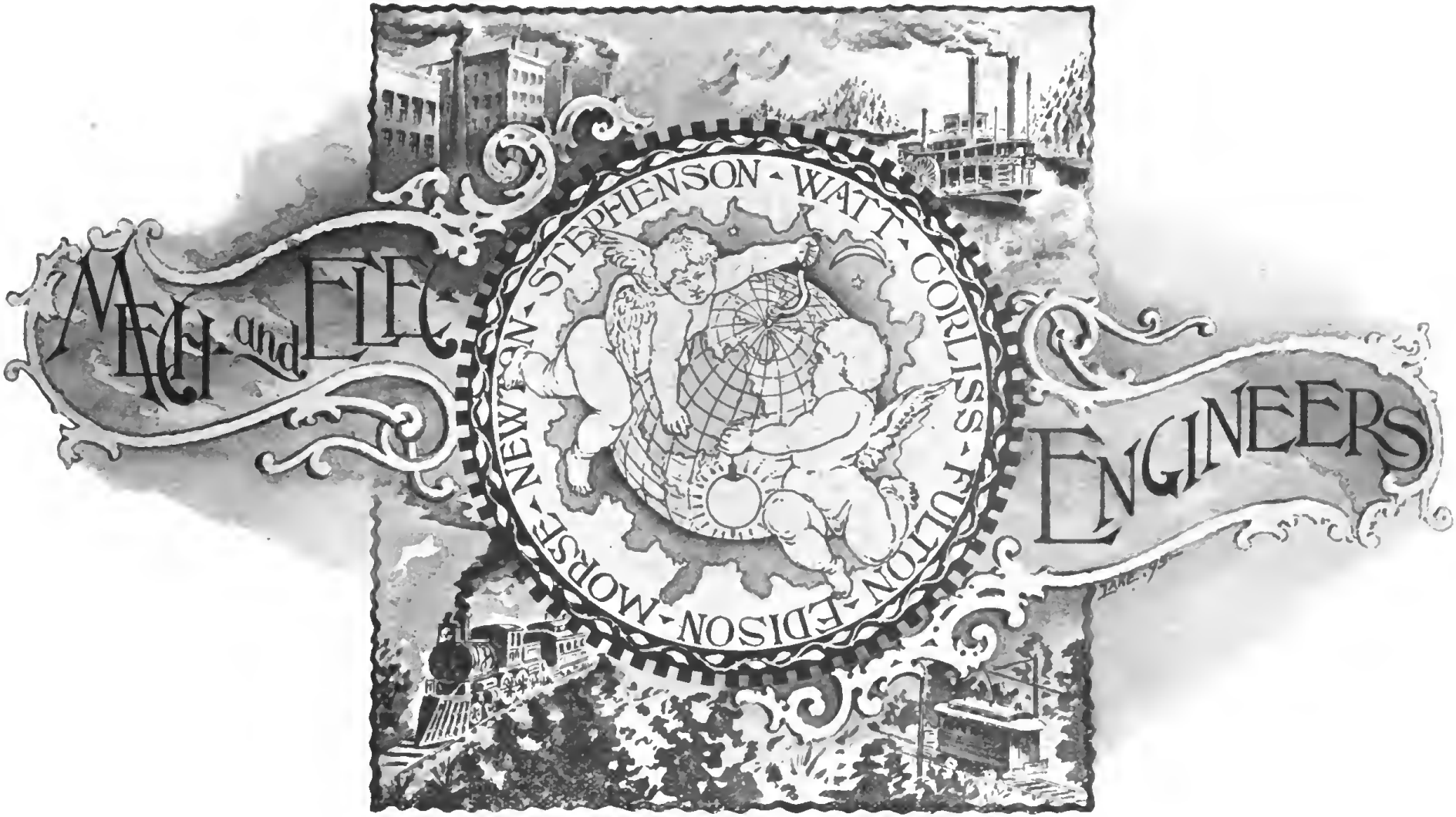
3. Be courteous and generous to your subordinates. In this matter let the golden rule guide your action. One of the ways in which this rule is violated is in passing judgment upon the works of others, in the way of fault-finding and belittling them, picking flaws, making small criticisms of design and method. Does any engineer imagine he raises himself in the opinion of others by so doing, or in any way advances his own prospects of success? Criticism for the purpose of suggesting improvement is a good thing, but criticism for any other purpose is unworthy a true man. The world on a whole is fair in its estimate of men; it recognizes the generous everywhere, and is just as sure to condemn the opposite.

4. Guard as carefully as life itself a high standard of professional honor and integrity—whatever the measure of your professional success—whether wealth and reputation crown your career, or disappointment and poverty be your constant and unwelcome companions—let no taint of suspicion attach to any professional act or utterance. As young engineers you are nearly certain to have some severe trials in this matter. In his relations with contractors, in his recommendation of patented or special devices, in preparing reports that may influence the markets, the engineer is liable to have his judgment warped by subtle and corrupting influences. You will save yourself much annoyance and possibly some danger, if you will at all times maintain a character of unquestionable integrity. It should not be difficult for the conscientious engineer, jealous of his professional honor, to decide what is right and what is wrong.

Now I think I can show you an objective point ahead by means of which you shall be able to find a way of safety and honor through the darkest valley of trial and temptation. I ask, then, what is your highest aim as engineers? Is it to stand at the head of your profession, and secure wealth and honor? Or is it to scrupulously, conscientiously, and faithfully discharge the duties of the positions in which you are placed? If it is the former, then you have many chances of failure to one of success, for such success will often depend upon circumstances entirely beyond your control. If your highest ambition is to conscientiously and faithfully discharge the duties of your position, then success depends upon yourself, for it is assured by simple and constant attention to the requirements of each occasion as it arises.

Ability, wealth, position, are all excellent things to possess. They mean, or may be made to mean, influence, weight, and power; but they are not the things which determine the essential value of a man. The true worth is measured by his character, not by his abilities, not by his positions, not by his successes, but by what he himself is.

We may all reach this most perfect manhood by simply doing all our work under the fullest appreciation of the meaning of that one word duty. That you may all through your life be actuated by this high motive, is my earnest petition.


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NOTES ON STEAM BOILERS.

By L. P. Breckenridge, M. E., Prof. of Mechanical Engineering, University of Illinois.

It is by no means true that because a boiler of a certain design and setting works well in one place that its design and setting can be followed at another. It is reasonable to suppose that if exactly the same conditions existed at each place there would be no difference in the workings of the boilers. It seldom occurs that exactly the same conditions do obtain. Important differences lie in feed water, draft, kind of fuel and the fireman.

What is true of boilers themselves is also true of the details of the settings and attachments.

Accidents and difficulties are continually occurring, each of which brings with it some suggestion as to what should be done to prevent its occurrence in the future. The following are reported for the first time to the profession, although it is probable that they have been duplicated in the experiences of others besides the writer.

AN EXPERIENCE WITH A BLOW-OFF PIPE.

This plant consisted of six horizontal Tubular Boilers, two being 60″ and four being 48″ in diameter. A steam pipe connected each boiler to the main steam pipe, and in each of these connecting pipes was a globe valve closing against the pressure in its own boiler. Each boiler was tapped on the underside near the back end for a 2″ blow-off pipe.

The blow-off pipe from each boiler was connected to a common 2″ pipe back of the battery. The connecting pipes for the 48″ boilers were 1½″ being reduced to this size by means of a bushing in a 2″ ell about 4″ under the connection to the boiler.

In each of these pipes was a 1½″ globe valve. The common 2″ pipe back of boilers ran to the sewer. In it was a gate valve so that when this was closed the full boiler pressure could be obtained in the common pipe. When these boilers came into the charge of the writer, they were found to contain considerable scale, so much in fact that the space between some of the tubes was entirely closed or bridged over by scale. The first thing to be done was to get the scale out; the next was to prevent as far as possible its further formation. One after another of the boilers were attacked, first by scrapers and picks and afterward by using only distilled water (the returns from the heating system) in the boiler under consideration.

The boilers were blown (?) down every morning as usual. In a few days the engineer reported that one of his blow-off pipes was leaking badly and that he had shut down the boiler. Examination showed that the elbow (2″ bushed to 1½″) and the short pipe between it and boiler was filled with scale and badly burned. It was not possible to take down the entire line of blow-off pipes at that time, but for the boiler that was shut down the following method was adopted: A 2″ pipe was put in in place of the former 1½″ and a gate valve in place of the 1½″ globe valve; the connection to the common pipe was made by means of a cross in place of a Tee and a plug was put in the open side of the cross. This same arrangement was adopted for all the boilers as soon as an opportunity presented. In addition to the above the following device was made in order to loosen any scale which might again fill into the blow-off.

The top of an old globe valve was threaded to fit the cross mentioned above, and in place of the usual valve stem, a long rod was inserted having a handle formed on one end and a slight bend or hook on the other end.

This device proved to be of service. The large amount of scale that came off the tubes would fall into the blow-off pipe and almost prevent any flow outward, even when the valve was opened. By screwing the "cleaner" into the cross and then opening the gate valve the long rod could be run into the pipe to the elbow and by a few turns the hook on the end loosened up the scale and it was blown out clean. In the course of a few weeks the scale in the boilers was reduced so much that there was not

any trouble from stoppage, and the "cleaner" was hung on the wall as useless.

Soon afterward a "Live Steam Feed Water Heater" (Hoopes) was put in above the boilers and no more scale was allowed to get into the boiler.

WATER COLUMN CONNECTIONS.

There is considerable difference of opinion as to the best way of connecting water columns to boilers. The following statement in connection with the method of attaching a column to a 100 H. P. horizontal tubular boiler will show that in this case a better method of attachment could have been devised.

The boiler under consideration consisted of a shell 66 inches in diameter and 18 feet long. It had 105 three inch tubes. It was set over a grate three feet long by six feet wide. The distance from the boiler to the grate was twenty-seven inches. The fuel used was anthracite culm. The draft was produced by a steam jet blower, and in a test made a short time before the following accident happened, thirty-one pounds of coal were being consumed to a square foot of grate surface, the evaporation being at the rate of nearly 3,400 pounds of water per hour. It was customary to blow down the boiler twice each day, at 5 o'clock in the morning and at 5 o'clock in the evening. The boiler was running continuously, night and day, sometimes for a period extending over three months. The shell of the boiler was 7-16 of an inch thick and the heads ⅜ of an inch thick. It was made of Speng steel of a tensile strength equal to 60,000 pounds per square inch. The boiler was being blown down as usual at 5 o'clock in the morning, and the engineer, while watching the water column, was to signal the fireman when to close the blow-off. After blowing for some minutes without any perceptible fall of the water in the glass gauge, the highest try-cock was opened and water freely flowed from it. It was thought that the boiler was pumped very full of water and the feed pump was stopped, the blow-off cock closed, but steam was continually drawn from the boiler as usual. The water in the glass gauge did not fall very rapidly and again the blow-off cock was opened. All of this occupied from twelve to fifteen minutes. Suddenly all of the water in the glass gauge dropped rapidly and went out of sight. This presented an entirely new feature of the case, be-

cause it suggested that the water in the boiler was below the top row of tubes, and perhaps lower. It was not deemed advisable to start the feed pump, but the dampers of the boiler were immediately closed and a thick layer of ashes thrown over the fire. The steam valve leading from the boiler was closed and the boiler left to itself.

As soon as the steam pressure went down and the boiler could be inspected, the following was found to be its condition. The front sheet over the fire was found to have drawn down at points about ten inches from the side walls for a distance of nearly one inch. The amount of water in the boiler was not over two inches deep. The front and back heads were pushed out by the expanded tubes for at least 5/8 of an inch.

The following repairs were necessary in order to put the boiler into shape. About one half of the tubes were safe-ended. An entirely new sheet was put in over the fire extending entirely around the boiler. This boiler had been running not over thirty days, and was one of a battery furnishing steam to several large engines. The internal condition of the boiler, as far as scale was concerned, was clean. The following conclusions were drawn after a careful inspection of the boiler, as to the cause of this accident. The water column was connected to the steam space by a one inch pipe tapped directly into the top of the boiler, back about ten inches from the front head. This led to the top of the water column, and in this pipe was a globe valve. The bottom of the water column was connected by means of a one-inch pipe to a hole tapped in the front of the boiler about eight inches from the bottom and to the right of the man-hole, which was below the tubes. In this pipe there was also a globe valve. During the time that the boiler was being blown off there is no doubt but what the globe valve in the pipe between the steam space of the boiler and the water column was closed. The valve in the pipe below the water column was open. Under these conditions water showed in the glass gauge up as high as the top try-cock, and also was blown out at this try-cock whenever it was open. As soon as the water level in the boiler fell to a point at which the boiler was tapped for the bottom connection of the water column, that is about eight inches from the bottom, the water immediately ran out of the glass gauge. It

is evident that at least for five to seven minutes a large portion of the bottom of the boiler, as well as nearly all of the tubes were exposed to the intense heat of the fire and escaping gases on one side with only steam on the other side.

The following recommendations were made in this case, and it has been the practice of the writer to always make corresponding recommendations for water column attachments: Tap the boiler for bottom water column connections as near the level of the top row of tubes as possible. Omit valves between water column and boiler. If there had been no valves this accident could not have occurred; also, if the lower connections had not been so near the bottom of the boiler, it would also have been prevented.

TWO BULGES.

Through the thoughtfulness of Mr. J. N. Chester (U. of I., '91), Assistant Engineer of the "American Debenture Co.," the Mechanical Engineering Department has recently received two fine examples of bulges. As they both came from the same place in the same boiler, they become more interesting than otherwise, the second bulge occurring in the patch put on where the first bulge was cut out. The trouble occurred at the Ashtabula, O., water-works. The details which Mr. Chester sent the writer are so complete that his statement of the case is given completely.

"When the 'bulge' came down the writer happened to be at Ashtabula making some improvements, and my attention was first called to it by the first engineer at the pumping station, but he had first blowed and washed out the boiler. In answer to my question as to what he found on the inside, over the bulge, he stated, only a small handful of loose mud, such as would naturally settle from a water turbid as Lake Erie's. The boiler is 16 ft. by 72″ return tubular, containing 72 4-inch flues, manholes in front, above and below flues. The shell of boiler is composed of 3 sheets, each one forming an entire circumference of the boiler.

"The 'bulge' occurred on the rear of the crown or fire sheet in the lowest part, just forward the seam between the front and middle sheets; (the rivet holes in the piece that you have being

a portion of that seam). The vital question was, what caused the trouble?

"On lower half of the inside of the shell and the upper half of the tubes was found a hard scale (of which samples have been sent you) varying from one to three thirty-seconds of an inch in thickness, and flaking off in some places. It seemed probable that currents or eddys in the boiler might have caused a deposit over this place, but the engineer's report destroyed this theory.

"A good mechanic, owning a machine shop at Ashtabula Harbor, and one who has had a wide experience with marine boilers, contended that it was grease, but as we use jet condensers and our boiler feed suction extends 30″ below the overflow of the hot well, his theory could not be credited. A Mr. Calder, Chief Mechanical Engineer of the Monomone Boat Line, examined it and said that the boiler had been flued too close to the shell, causing steam pockets, and cited cases in Chicago to prove his argument.

"The writer had entertained the idea of a flaw, but not very strongly however; the matter was reported to our Mechanical Engineer, Mr. E. L. Street, who ordered the 'bulge' cut out and a patch put on, which was done.

"As an excess of scale had been found, inquiries were made as to the amount of compound used, and it was found insufficient according to the directions of the manufacturer, to remove or even keep out the scale. The use of the amount prescribed for the removal of scale from Lake Erie water was at once ordered.

"Four days after the patch was put on, while making an evaporative test to determine the relative values of coal used, it was discovered that the patch was coming down in the same manner as the original sheet. On conclusion of the test, the boiler was ordered shut down under brisk fire (patch showing burning) and not to be molested until the writer himself should do so. Two days later on coming to the pump house to conclude investigation, it was discovered that the boiler had been blown off to a considerable extent after my having ordered it shut down. The engineer was taken to task, but claimed that it was the custom to blow off each day and saw no reason why he should make an exception in this case. While he was forgiven outwardly, after a severe reprimand, we still think it was his design

to defeat our purpose, as my theory was that the boiler being shut down under the conditions above stated and allowed to cool off and the water run out, the cause could be discovered. As blowing off would tend to disturb the conditions we had expected to find, the boiler was ordered fired up again and run to a considerable length, and with the patch burning as before shut down. After three days the blow-off was opened by myself, and when the water was out, removed the lower man-head and over the patch was just what had been predicted, only more so, loose scale to the depth of $3\frac{1}{2}''$ over a space $12''$ long and $18''$ wide. The current over the fire being up and dividing forward and backward, and along the bottom toward the spot where the bulge occurred.

"The scale stood on edge at about 30° from the vertical and was arranged in semi-circles on the horizontal (see specimens) it was matted in and banked with mud. Some two-inch plank were placed in the boiler on cross sticks, taking care not to disturb the scale, the writer crawled in and spent an hour picking in pieces and studying this phenomena. On further investigation, the entire fire sheet was found to be bagged to the amount of one-eighth of an inch, showing its elastic limit had been exceeded.

"When the second report reached Mr. Street, he ordered the removal of the entire sheet and replaced it with a new one. This necessitated the removal and replacing with new of thirty-four flues at an entire expense of about four hundred dollars.

"Conclusion: The engineer certainly misrepresented in regard to existing conditions after the first 'bulge,' as no blowing off could have removed conditions found in second case, it being mudded and baked so hard that it required considerable effort with my fingers and nails to remove. Had we understood the situation correctly, the second calamity could have been averted by removing the scale with hammers or the use of compound, light fire and cleaning after every 24 to 36 hours' run.

"As it is, the engineer has lost a job that paid seventy-five dollars per month, with the allowance of house rent, light, fuel and water. It might be stated further that his services for some time have been unsatisfactory. We have ordered the patch removed from the sheet and sent to the U. of I."

In answer to a later letter to Mr. Chester, the following facts in addition to the above were sent.

"Distance from grate to boiler 30″.

"Distance from bridge wall to boiler 12″.

"Bituminous coal used for fuel; mixtures of various sizes. Feed water was fed in to boiler at the back end and through the blow-off pipe. Fires never banked.

"Boilers were generally run two weeks and then shut down, allowed to cool off, the water run out, and cleaned.

"On day of second occurrence temperature of feed direct from mains was 38° F. and boiler developed for ten hours 160.6 H. P."

THE MOST ECONOMICAL LIFE AND EFFICIENCY OF INCANDESCENT LAMPS.

By W. L. Abbott, '84. Mechanical Engineer, Chicago.

Before entering into the discussion of this subject it should be stated that the data here used relating to the variation in the condition of incandescent lamps under various pressures are taken from published accounts of tests made by various parties, which are, from the closeness which they check each other, presumably correct. Also that the candle power of the lamps is taken as the horizontal measurement perpendicular to the plane of the filament.

Filaments made of the same material and under similar treatment in various shops have the same characteristics, although bearing different factory names, and nearly all the real difference will be found in their cross sections and lengths, and lamps of different efficiency and of the same or different makes may be made to have the same efficiency when each is run at a certain voltage. For example: If a lamp be run at a pressure of 110 volts and is found to give 16 candle power at an efficiency

of 3.6 watts per candle power, and the pressure is then raised to 114 volts, it will give an illumination of 20 candle power at an efficiency of 3.1 watts per candle power. Or if the pressure be lowered to 108 volts, the lamp will give only 13½ candle power at an efficiency of 4 watts.

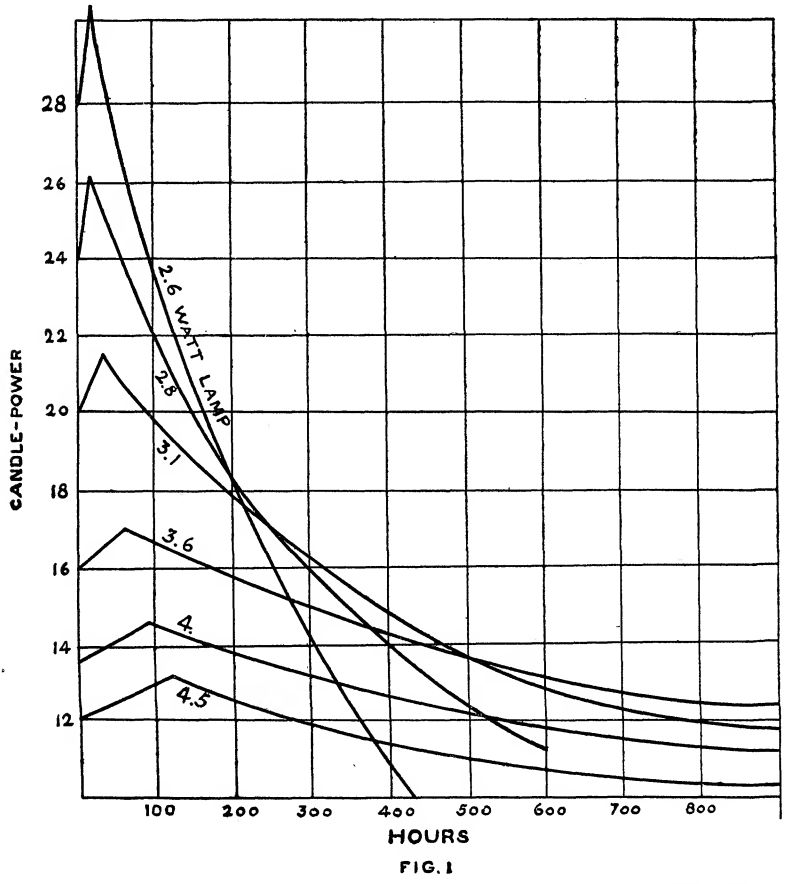


FIG. 1

Variation in candle power of lamps having filaments identically alike, but run at different pressures.

It is well known that the greater the initial efficiency of lamps the shorter their life, and the farther and more rapidly they will deteriorate with use.

Figures 1 and 2 show the change in candle power and efficiency which similar lamps of various initial efficiencies under-

go during their lives, from which may be observed that a lamp if run at a very high initial efficiency loses its candle power so rapidly as to soon become worthless; whereas if it were run at a low efficiency it would, after a few hundred hours' burning, reach a condition which it would maintain almost indefinitely, but it would produce light only at great expenditure of power. If fuel cost nothing, a low efficiency lamp would be the best to use.

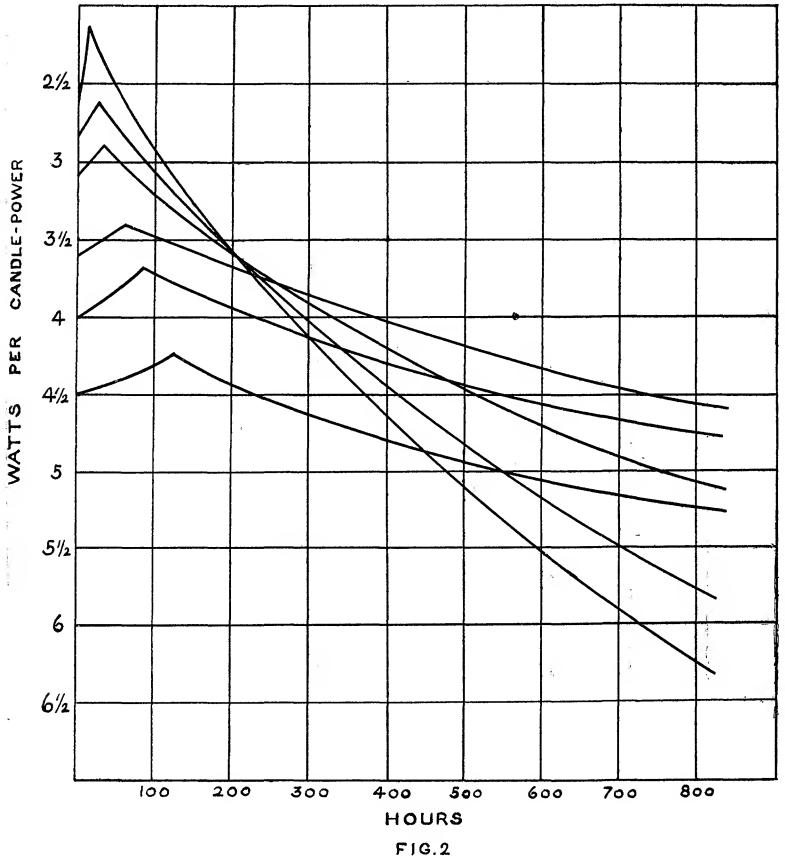


FIG. 2

Variation in efficiency of lamps having filaments identically alike, but run at different pressures

The object of this discussion is to determine the most economical efficiency at which to run lamps in order to produce a

given illumination, taking into consideration all the expenses of operating a lighting plant.

If we use a lamp of high efficiency, less power will be required and the entire operating expenses, except for lamp renewals, will be small, and the lamp renewal bill will be large. If, on the other, we use lamps of low efficiency, the bill for lamp renewals will be low, and the other operating expenses high. Also, as the efficiency of all lamps diminish steadily after a few hours' burning, they will eventually reach a point beyond which it will not be profitable to run them.

These are the two points to consider: First, the efficiency of the lamp; and second, the life of the lamp. To settle the problem distinctly:—

For a definite amount of light required, the most economical lamp life and lamp efficiency for which to provide in building a lighting plant to furnish the desired illumination.

Let us take a practical case of a factory or store requiring an illumination of 40,000 candle power for ten hours a day and 26 days a month.

To generate this amount of light we would usually provide two hundred horse power, which could be installed complete, with dynamos, circuits, etc., for about $20,000. The monthly cost of laber to operate this plant might be as follows:

Superintendent	$ 100 00
Engineer	90 00
Electrician	75 00
Helper	50 00
Fireman	60 00
Total	$ 375 00

To develop the 2,000 electrical horse-power hours required for a day's run would require in the case of a non-condensing steam plant of this size and kind, 30 lbs. of water for each electrical horse-power hour, or 60,000 lbs. of water for a day's run. To this add 20% lost in friction of the machinery, making a total of 72,000 lbs. of water evaporated daily. Under moderately good conditions this can be done at a cost for fuel of 15 cents per 1,000 lbs. of water, or for the day's run, $10.80. To this add 5%

for fuel used in getting up steam and otherwise lost, and we will have a daily coal bill of $11.34, or for a month of 26 days, $295.

The fuel and other bills, which vary nearly with the load, are as follows for a month:

Fuel	$ 297 00
Oil and waste	25 00
Water	14 00
Carting away ashes	25 00
Total for month	$ 361 00

There is another class of expenses which are sometimes called general expenses. They are made up as follows:

Interest on $20,000 at 6%	$1,200 00
Taxes	400 00
Insurance	400 00
Repairs and depreciation 15%	3,000 00
Rent, or value of space	800 00
Incidentals	200 00
Total annual general expenses	$6,000 00
Or for a month	500 00

The monthly operating expenses, exclusive of lamp renewals, are thus made up of these items:

Labor	$ 375 00
Supplies	361 00
General expenses	500 00
Total	$1,236 00

Each of these items will be greater or less depending upon the work which is done and for which the plant is built, but they will not vary in the same ratio. Should the capacity and work of the plant be doubled the labor will be increased 33%, the fuel, etc., 80%, and the general expenses will be increased 55%.

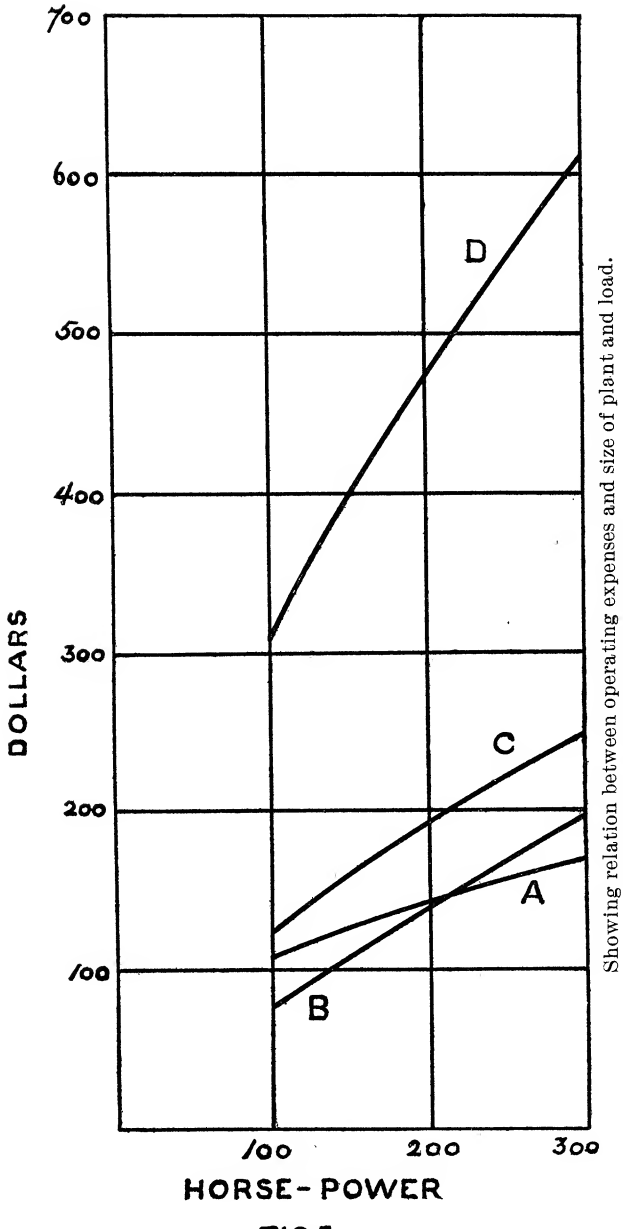


FIG. 3.

Showing relation between operating expenses and size of plant and load.
Curve A—Cost of labor for 100 hours.
Curve B—Cost of supplies for 100 hours.
Curve C—Cost of general expenses for 100 hours.
Curve D—Total operating expenses, except for lamps.

If the capacity and work be diminished one half, the various operating expenses will decrease according to the same ratios. The variations in these three sets of expenses are shown graphically in curves A. B. and C. of Fig. 3, and the variation of the total operating expenses, lamps excepted, is shown in Curve D., which is derived by adding the abscissae of curves A. B. and C. These costs are for operating 100 hours.

TABLE I.

1	2	3	4	5	6	7	8	9	10	11	12	13
100	20 4	20 4	20.4	1961	588.	6200	12157	122.	413.	413	1001	.0250
200	18.7	39 1	19 5	2051	615	12400	25432	127	425.	850	1465	.0183
300	16 8	55.9	18.6	2151	645.	18600	40009	133.	435.	1305	1920	.0162
400	15 7	71.6	17 9	2235	670.	24800	55428	139.	445.	1780	2450	.0153
500	14 2	85.8	17.1	2339	702.	31900	72509	145	460.	2300	3002	.0150
600	13.1	98 9	16 5	2424	727.	37200	90173	150.	470.	2808	3535	.0148
700	12.6	111.5	15.9	2516	755.	43400	109194	156.	479.	3553	4118	.0147
800	12 1	123.6	15.4	2597	779.	49600	128811	161	495.	3960	4739	0148

Having before us the curves of Figs. 1, 2 and 3, we should be able to determine the cost of maintaining 40,000 candle power with each of the various lamps taken. The method of determining this is shown in Table No. 1, which discusses the 3.1 watt lamp only.

Column 1 gives the number of hours which the lamp runs.

Column 2 gives the average candle power during each 100 hours from the time the lamp is started.

Column 3 gives the total candle power hours of the lamp from the beginning of the run to the end of each 100 hours.

Column 4 gives the average candle power during the same time.

Column 5 gives the number of lamps required to produce a constant illumination of 40,000 candle power when each lamp is allowed to attain the age indicated in Column 1.

Column 6 gives the cost at 30 cts. each of the number of lamps given in Column 5.

Column 7 gives the total number of watt hours consumed by the lamp in question at the end of each 100 hours.

Column 8 is the product of the numbers of Column 5 into the numbers of Column 7, divided by 1,000, and is the number of kilowatt hours required to maintain 40,000 candle power for the time indicated in Column 1.

Column 9 gives the average number of kilowatts consumed by the lamps of Column 5 in 100 hours. It is obtained by dividing the numbers of Column 8 by the number of hours the lamps have run.

Column 10 gives the cost of everything but lamps for doing the work of Column 9 for 100 hours. This is derived from curve D. of Fig. 3.

Column 11 is the costs as given in Column 10, multiplied by the number of hundreds of hours which each is to run.

Column 12 is the total cost of lamps and power, and is obtained by adding the corresponding numbers of Columns 6 and 11.

We have now determined the costs of maintaining 40,000 candle power for one hundred hours with lamps having an initial efficiency of 3.1 watts, and run for various lengths of time. If we will now divide the cost of producing the light by the number of candle hours produced we will be able at a glance to tell which is the most economical length of life for this particular lamp. These quotients are given in decimals of a cent in Column 13, and an inspection shows that with the cost of power and lamps as assumed, by using a lamp having an initial efficiency of 3.1 watts, 40,000 candle power can be maintained the cheapest by removing the lamps from circuit at the end of 700 hours.

The numbers in columns 6, 12 and 13 are platted in curves A. B. and C., respectively, of Fig. 4. Curve A. shows the cost of lamps. Curve B. is the total cost for power from the beginning laid off above the cost of lamps. The abscissae of this curve at any point show the cost of maintaining 40,000 candle power for the numbers of hours indicated, assuming that all lamps are to be removed from circuit at that age.

Curve C. is the quotient obtained by dividing the total number of candle power hours run by the cost of operating during that time. These quotients are multiplied by ten million so that the variations of curve C can be seen on the same diagram with curves A and B.

In the same way lamps of other initial efficiencies have been investigated and the final results are shown in the curves of Fig. 5, which are increased as curve C in Fig. 4, from which we find that the most economical lamp to use, under the conditions we have assumed, is a 3.1 watt lamp, and the most economical length

of time to run it is 700 hours. We also see that with this lamp there is very little difference in cost if the lamp is run 400 hours or 900 hours.

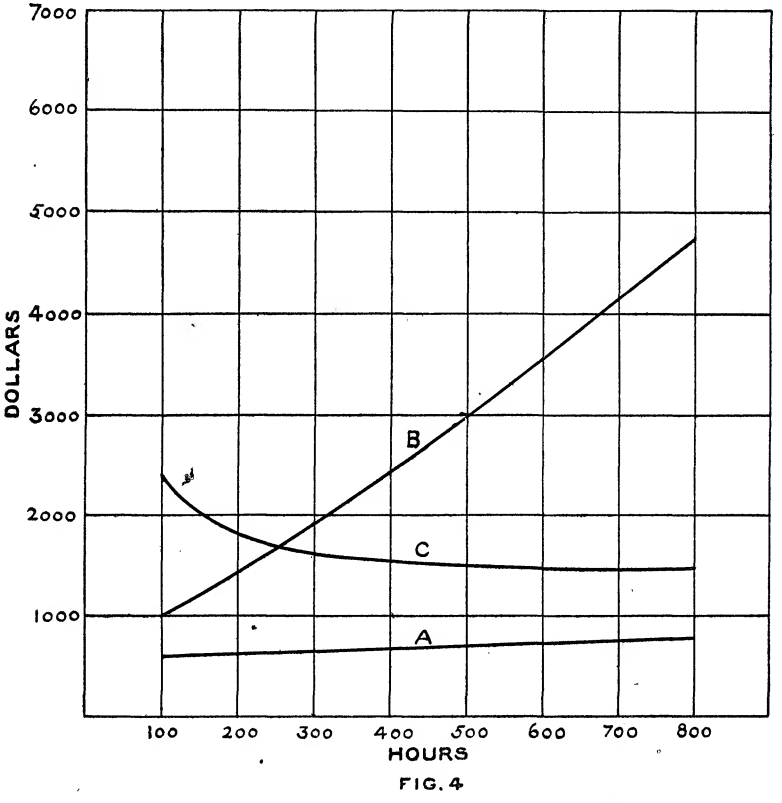


FIG. 4

Showing relation between operating expenses and number of hours lamps are used. For 3.1 Watt lamp.
Curve A—Cost of lamps necessary to maintain 40,000 candle power.
Curve B—Total operating expense for same.
Curve C—Cost of producing ten million candle power hours of light using lamps of various lengths of life.

It may also be seen that there is very little difference in the cost of producing a given amount of light with lamps of various efficiency, *provided the plant is adapted to the load and lamp used.*

It may also be proven that if a lighting plant using 4 Watt lamps 800 hours each were loaded to its full capacity, the out put of light could be increased 20% by using 2.8 Watt lamps,



ELECTRICAL LABORATORY.

which would increase the operating expenses only 12 per cent. No account is taken here of the loss of lamps by breakage, for the reason that when lamps are run at the efficiencies given the breakage within 800 hours would be so small that it could be neglected, except in the case of the 2.8 Watt lamp, and its curve

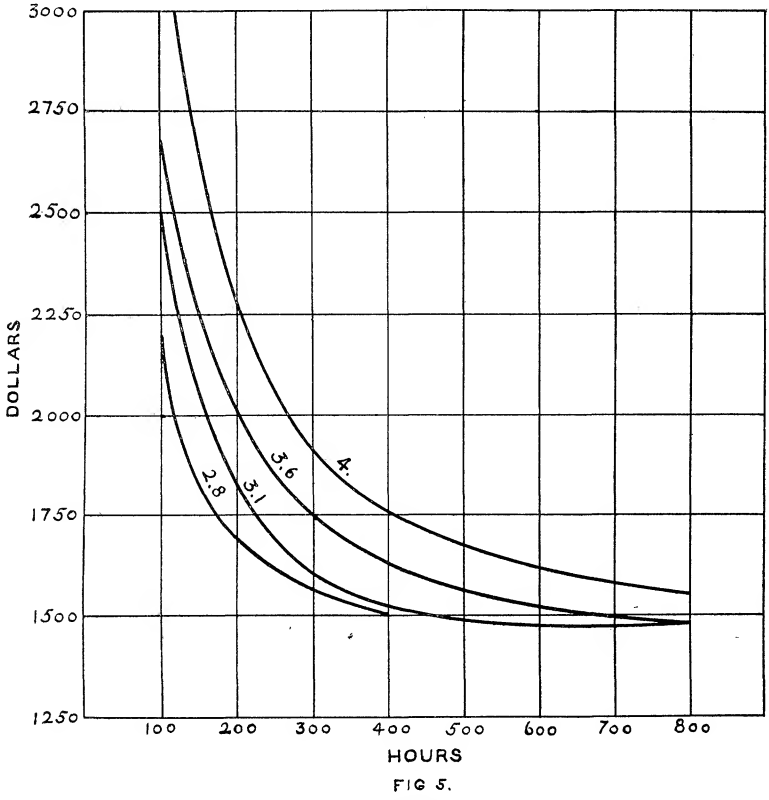


FIG 5.

Curves showing the cost of producing ten million candle power hours of light using lamps of various initial efficiences and of various lengths of life.

in Fig. 5 stops at 400 hours. As the lamps will not break during the time of their useful life, it will be necessary for the Station Superintendent to go around every day and remove lamps which are still burning and giving fairly good service, and while there is yet several hundred hours' life remaining to them. A Superintendent who will do this of his volition the world has never seen.

COST OF MACHINE TOOLS PER POUND.

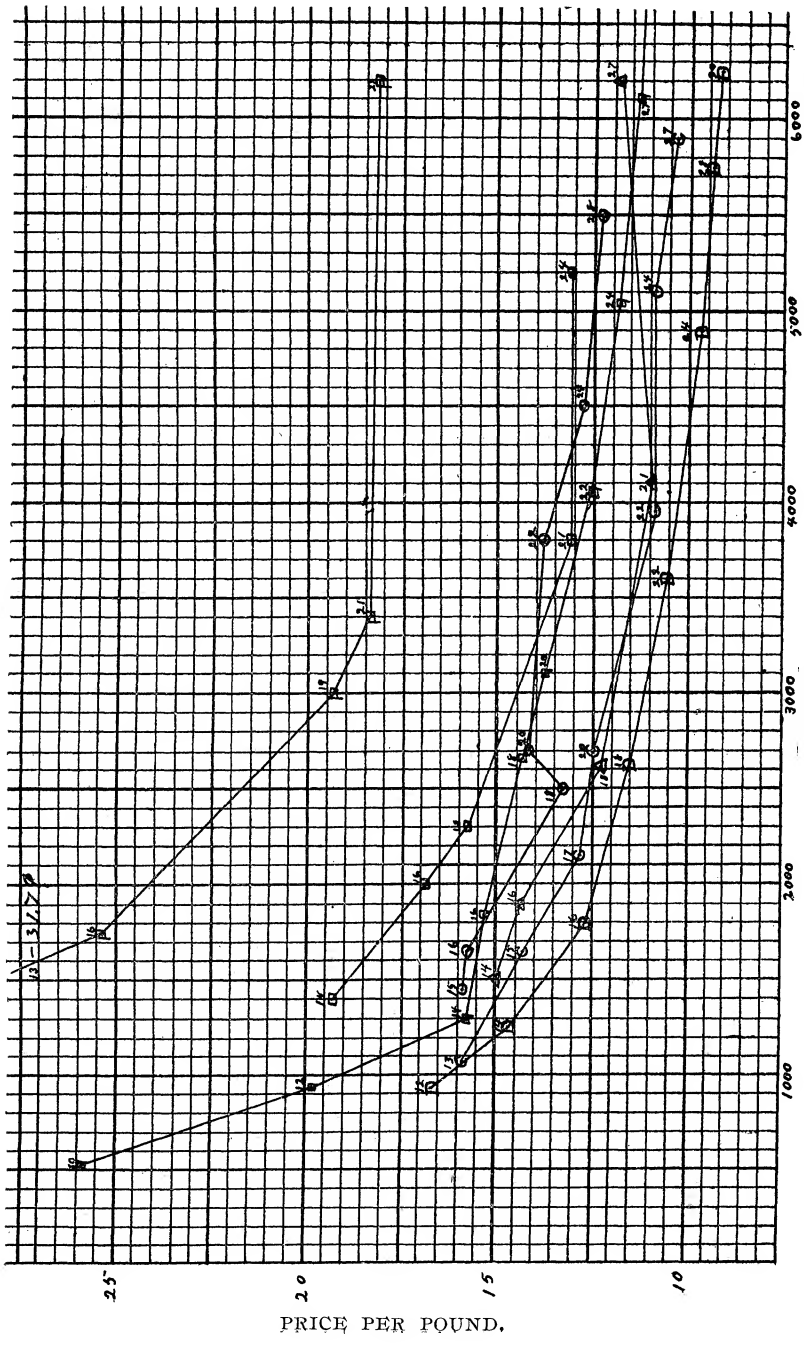
By W. H. VanDervoort, M. E., Asst. Prof. Mech. Eng.

The great improvements made during the past five years in the manufacture of machine tools have been due, largely, to the persistent efforts of our manufacturers to improve their tools in points of design, material and workmanship. Experience, experiments, introduction of the interchangeable system and use of standard gauges, jigs and templets are the principal factors that have brought about these marked improvements.

The reduction in price from time to time of the material used in their construction, the use of this same improved machinery for their manufacture and superior methods, together with the building in large quantities under efficient management, have with a brisk competition brought about very marked reductions in prices of machine tools. We can now purchase a superior tool for much less money than a few years since. The machine tool that fifteen years ago cost $1,000, can be replaced today at one half the price, by a modern one of the same principal dimensions, and capable of performing twice the amount of work with a greater degree of accuracy.

The value of a machine tool of any class depends upon its design, weight, and the accuracy with which it has been constructed. That these elements vary largely in similar tools by different makers is evident The cost of production depends not only upon these factors, but also upon the amount of labor expended in finishing parts for looks only, as one-half the polished work on the average lathe adds nothing to its accuracy or efficiency, but does add quite sensibly to its cost.

Since the weight, accuracy, general design and finish of these tools vary so much, it would not be possible to establish a standard price for all. It would perhaps be within the limits of a reasonable possibility, however, to say that the different classes of machine tools should cost so much per pound of net weight, inasmuch as the prices vary quite uniformly with the weights;



PRICE PER POUND.

WEIGHTS.

Numbers at points indicate swing in inches.

No. 1.

and again, in order to arrive at approximately accurate results it might be necessary to subdivide the tools under say two, or even three heads, graded according to quality.

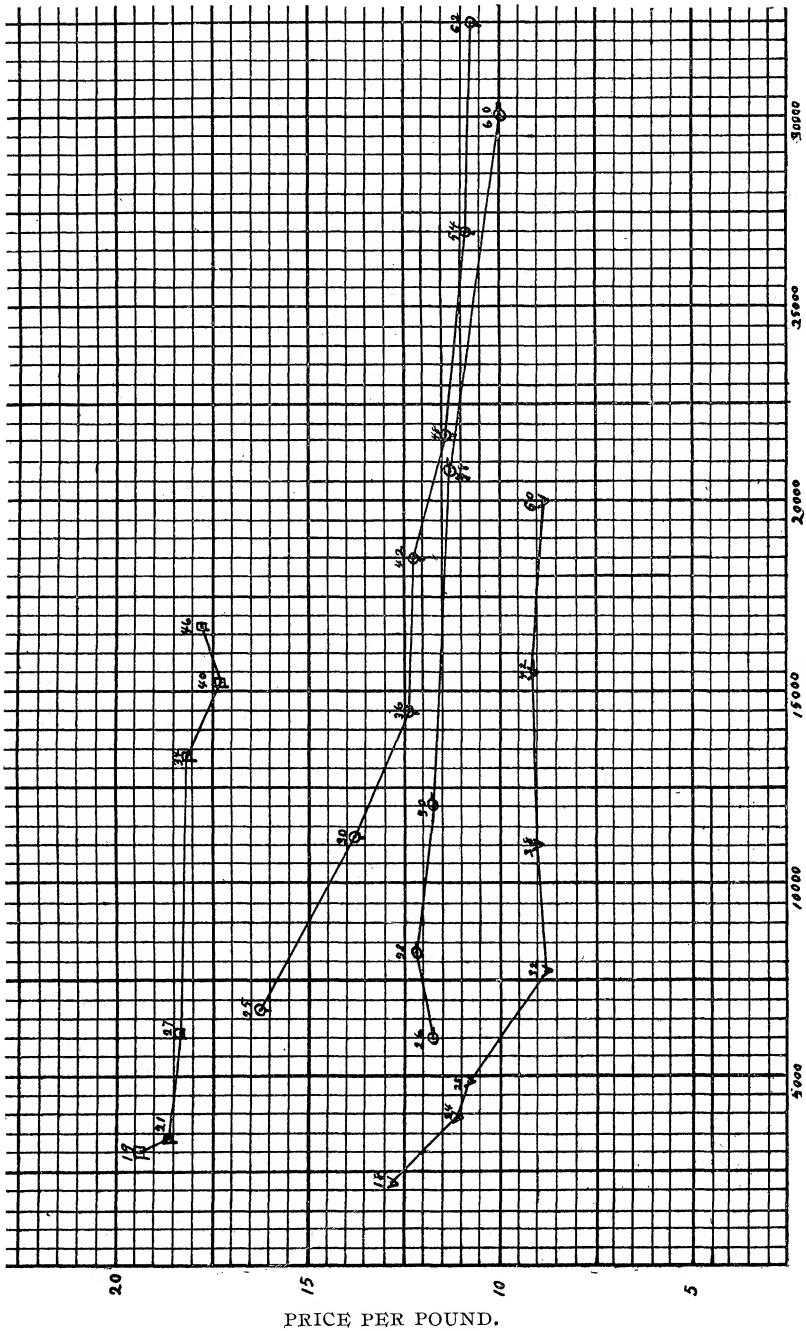
Through the courtesy of many of our leading machine-tool builders, complete lists of tools with their net weights and regular selling prices have been received. On most of these tools there would be a discount of from ten to twenty per cent., but in all cases regular selling prices have been used.

In the accompanying plates weights are represented by the horizontal co-ordinates, and prices per pound by the vertical.

Plate No. 1 shows the price curves of engine lathes from ten to thirty inch swing, as built by seven of our leading builders. The swing in inches is indicated at every point of each curve. Five of these curves show a comparatively uniform decrease in price per pound as the weight increases. This is most clearly shown in the lowest curve. Two curves show increase in price per pound for increase in weight, at two points, the most striking being shown in curve, points of which are indicated by "o" at 18 inches swing where the price is 13.25 cents per pound. For 20 inches swing the price is 14.2 cents per pound, from which it gradually falls for 22, 24 and 28 inch swings, being 12.25 cents per pound for the latter. The sudden increase in price at that point is probably due to one or both of two reasons; 1st, The demand for the small swing lathes of this make warrant the building in larger lots up to and including the 18 inch swing, thus considerably lessening the cost of manufacture; 2nd, The lathes above the 18 inch swing might be regularly equipped with what are commonly considered as extras, as compound rest, full swing rest, follow rest or taper attachment. It will be noticed that six of these curves follow very approximately the same general curve, the prices varying not to exceed two cents per pound either side from the general curve. The upper price curve on this plate is for a lathe which for accuracy has gained a world wide reputation. Every refinement in lathe building is used in its construction, which increases the cost of production and throws the curve high. The 13 inch swing lathe of this make costs 31.7 cents per pound.

Plate No. 2 shows four price curves on heavy lathes from 18 inch to 62 inch swing. As most of these large lathes are built

No. 2.



Numbers at points indicate swing in inches.

to order, we should not expect to see marked uniformity in these curves.

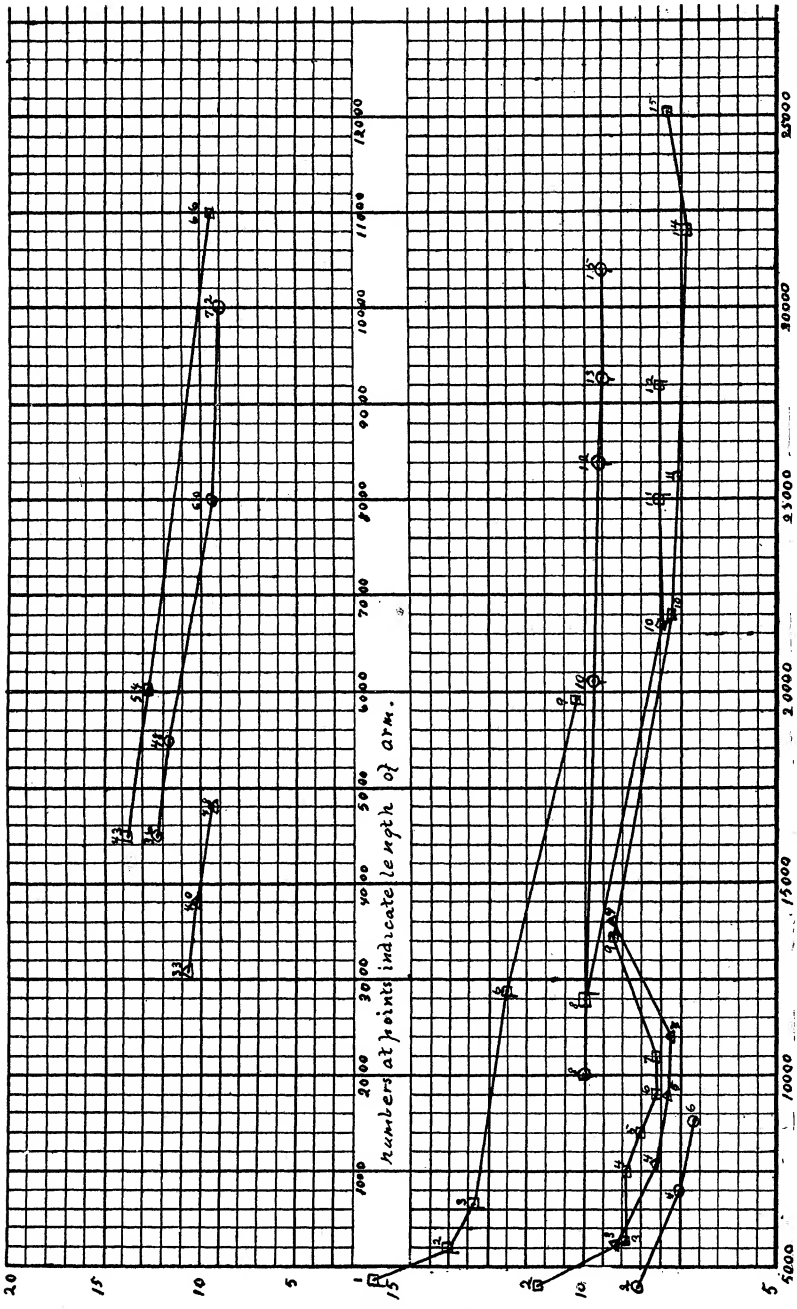
That the selling price of a lathe is governed largely by its weight is shown by the following: In six 30 inch swing by 12 foot bed lathes, by six different makers, the weights range from 6,050 pounds for the lightest to 11,400 pounds for the heaviest. The price of the former is $640. or 10.65 cents per pound, of the latter $1560. or 13.68 cents per pound. Weights and prices on the other four fall within these limits. In general a 30 inch swing by 12 foot bed engine lathe complete would list at very approximately 12 cents per pound, from which, if we take a fifteen per cent. discount, leaves 10.2 cents as the approximate cost per pound. The addition of a taper attachment to this same lathe would increase its cost per pound about one cent.

The upper portion of plate No. 3 gives price curves on plain radial drills by three makers. It should be noted how uniformly the price falls as the weight increases.

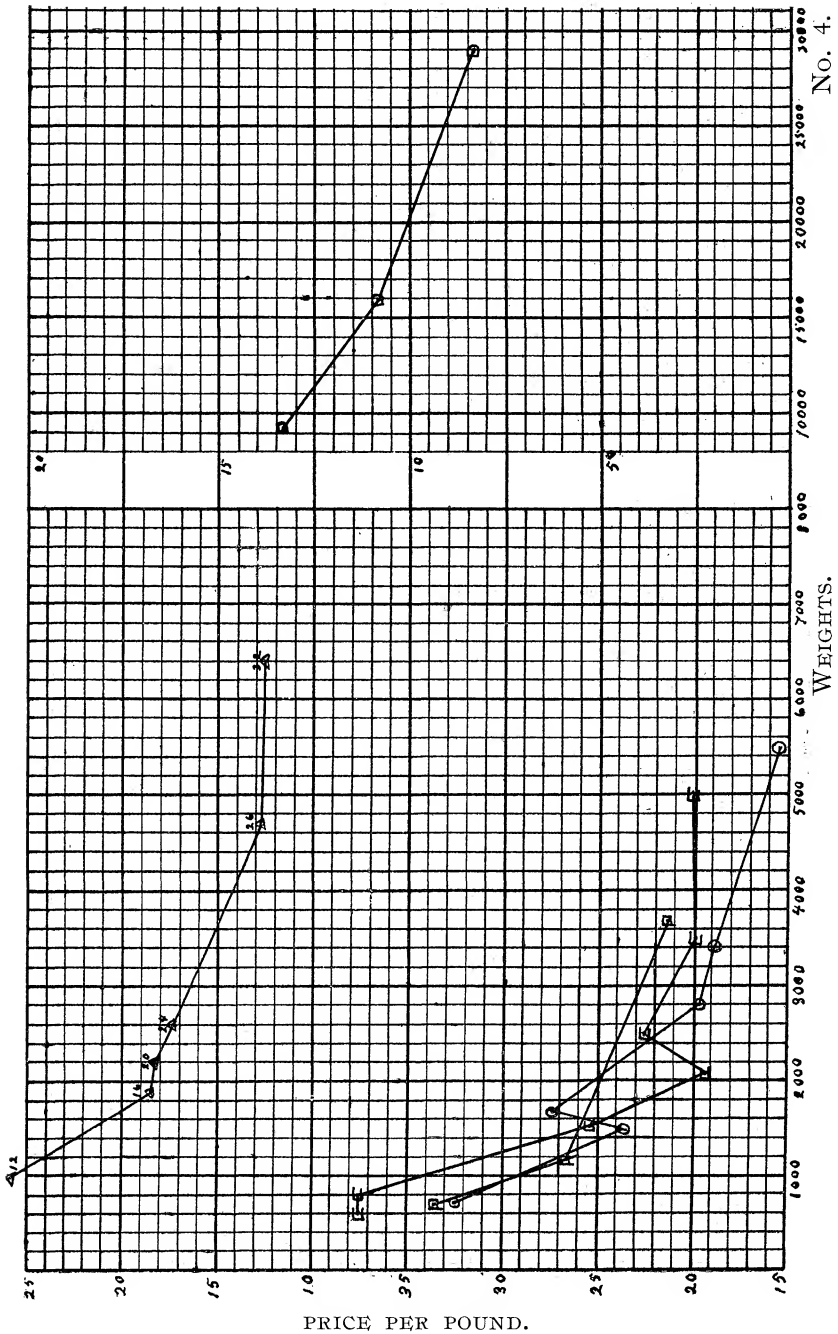
The lower portion of plate No. 3 gives six price curves on planers by as many different makers. The upper curve gives prices on the planers manufactured by the same company that manufactures the super high grade lathe, prices of which were given by the upper curve of plate No. 1. For the planers under 32x32x8 the prices decrease quite uniformly with the increased weights. At that point there is a sudden rise in price per pound, due perhaps to one of the two reasons given for the sudden rise in price for lathes of a certain swing, or more probably to the fact that comparatively few manufacturers are in position to build such heavy tools, consequently competition is less and prices are higher. On the curve, points of which are indicated by the small squares, the price increases uniformly from 7.75 cents per pound for the 60x60x12 planer to 10.9 cents per pound for the 96x76x14.

The curve in the upper left-hand corner of plate No. 4, gives the prices per pound on shapers from 12 to 32 inch stroke as built by one of the leading makers. The numbers at points indicate stroke in inches.

The curves in lower left-hand corner are price curves on plain milling machines of the column pattern by three different makers.


PRICE PER POUND.
WEIGHTS.
1=20×20×5
2=22×22×6
3=24×24×6
4=26×26×8
5=28×28×8
6=30×30×8
7=32×32×8
8=36×36×8
9=36×36×10
10=42×42×10
11=48×48×10
12=50×50×10
13=54×54×10
14=56×56×12
15=60×60×12
numbers at points indicate length of arm.

No. 3.


No. 4.
WEIGHTS.
PRICE PER POUND.

The curve on the right-hand side of this plate gives prices per pound on the three sizes of horizontal boring and drilling machines manufactured by one company.

Universal monitor lathes from 15 to 30 inch swing, cost approximately from 35 to 18 cents per pound.

Screw machines of the best make, from $\frac{7}{16}$ to $1\frac{1}{2}$ inch, cost from 70 to 33 cents per pound. An automatic screw machine, as made by one of our best makers, for making very small screws, costs 83 cents per pound.

The average cost per pound of four of the best cutter and reamer grinders on the market, is 43 cents.

A 12x12 inch standard surface plate costs 70 cents, and a 24x24 inch costs 48 cents per pound.

A modern ten-wheel freight locomotive, weighing 130,000 pounds, costs 7.38 cents per pound.

THE GENERATION OF STEAM.

By A. C. Broucher, '94, and W. B. Broucher, '95.

The primary object of this paper will be to mention briefly a few general facts in regard to every-day phenomena, and afterwards to describe a practical application of observed facts which will produce apparent results in the economical production of steam.

The most remarkable phenomena that we observe in every-day life, and with which we have become so familiar as to pass them by as matters-of-course, are such as pertain to the action of heat and pressure upon solids, liquids, and gases, and the transformation of matter from one condition to another by means of the addition or subtraction of heat or pressure.

Water is our most common and also most important sub-

stance, inasmuch as it is our great store-house of heat and power, and by its perfect adaptability to the various conditions of our atmospheric temperature and pressure, the amount of sensible heat in the atmosphere is regulated within very comfortable limits. The evaporation of water and the consequent absorption of the latent heat of evaporation keeps the temperature down in summer, and the condensation of the vapor in the upper regions of the atmosphere disposes of the heat at a distance and returns to us the cool and refreshing rain. The condensation of moisture and the formation of ice and snow give to the atmosphere of winter the latent heat of evaporation and the latent heat of fusion of ice and snow, thus keeping the temperature at or near the freezing point as long as there is moisture in the atmosphere to give up its heat in the formation of ice and snow. The water surface of our country is being so greatly reduced by drainage that the extremes of heat and cold will probably be much greater in the future than in the past.

Gas or air under pressure at ordinary temperature will absorb heat rapidly upon being allowed to escape into the atmosphere, or even into a compartment which is under less pressure than the original. This absorption of heat is sufficient to produce freezing in the case of air at a temperature of 60° and under a pressure of 60 lbs. when exhausted into the atmosphere. The same effect is produced in the natural gas regions, where the initial pressure of the wells is very high and is reduced by means of a reducing valve; and also where a small quantity of gas is allowed to pass through a valve for use as fuel, the pipe between the valve and the furnace becomes covered with frost. Steam escaping under pressure absorbs its own heat by expansion so rapidly that the hand may be held in the escaping vapor at a slight distance from the point of issue without discomfort.

Melting ice ordinarily absorbs all heat in the vicinity of an intensity equal to or in excess of the freezing point of water, thus keeping the temperature uniformly at or near the freezing point until all the ice is melted. If, however, the melting of the ice be forced artificially by the addition of salt or otherwise, care being taken to exclude the heat of exterior objects, the absorption of heat necessary to the rapid melting will reduce the temperature to a point near 0° F,or in other words the absorption of heat will extend to and include heat of a lower degree than the

freezing point in order to acquire heat sufficient to produce the enforced melting.

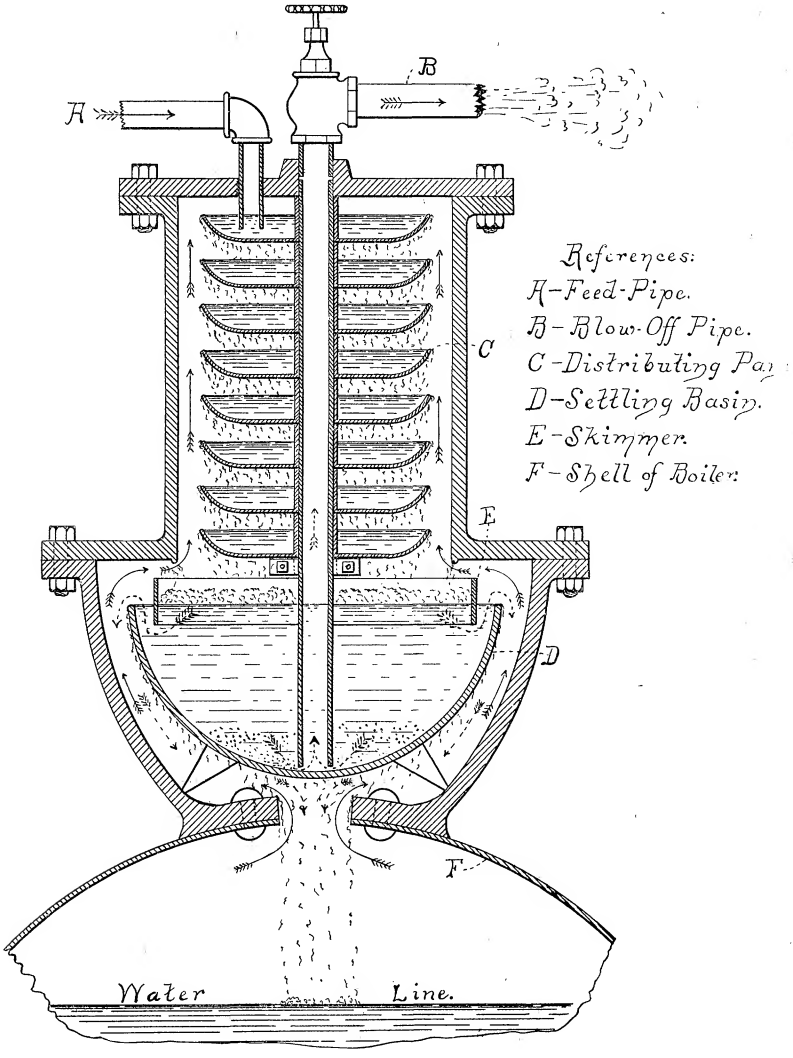
Boiling water absorbs and stores up as latent all available heat of an intensity greater than the degree at which the boiling takes place, depending upon the pressure to which the liquid is subjected. A reduction of pressure will produce an enforced evaporation and the heat necessary to accomplish that evaporation will be absorbed with avidity from the surrounding surfaces or from the body of liquid itself, depending upon the relative temperature of the two and also of the liquid in contact with the heated surfaces. If that liquid is below the point of evaporation due to the pressure, evaporation will not take place in contact with the heated plates, and hence the enforced absorption of heat from the heated surfaces will not take place.

Artificial refrigeration is produced by the rapid evaporation which takes place when a liquified gas under high pressure is discharged into the atmosphere or into a partial vacuum, the reduction of temperature being caused by the absorption of all heat above the boiling point of the liquid at the reduced pressure. Thus, liquid ammonia at 80° F., exerts a pressure of about 150 lbs. per sq. in. The temperature is reduced by the absorption of the latent heat of evaporation to 28° below zero, the temperature at which evaporation takes place, upon reducing the pressure to atmosphere. In like manner the temperature of water would be reduced from about 365° to 212° in discharging into the atmosphere from a pressure of 150 lbs. per sq. in., and could be frozen by discharging the vapor into a vacuum maintained by the condensation of the vapor by means of a very low temperature.

It is the evaporation of water and the resulting rapid absorption of heat that makes it efficient in extinguishing fire. If the water could not exaporate and could only absorb the heat by an equivalent rise in temperature, the water would become red-hot in a short time, and would be very little better in putting out fire than so much shot iron thrown upon it.

Cold water is a very poor conductor of heat, and can only be heated by connection when the point of application of the heat is below, as water may be boiled on the surface for hours by heating from above and remain unaffected below, while ice will not melt to exceed three inches below the surface with two hour's boiling at the surface.

The accompanying cut represents our invention, upon which patent has been allowed, which consists in the application of a heating and purifying chamber attached directly to the top shell



of the boiler, (F), by which the live steam under full boiler pressure comes in direct contact with the feed-water as it enters the chamber through the feed-pipe, (A), and flows downward over

the distributing pans, (*C*); the impurities are deposited upon the plates, (*C*), or settle or float in the settling and skimming basin, (*D*), while the purified overflowing water enters the boiler through the opening in the shell at the bottom of the chamber. The floating impurities are held by the skimmer, (*E*), until the valve or cock in the blow-off pipe, (*B*), is opened, when they are blown upward by the pressure of the steam through the blow-off pipe and removed from the boiler together with the water and settlings in the basin, (*D*).

The full boiler pressure having access to the dome or chamber will cause the water to be heated to the temperature of boiling due to that pressure. The steam in contact with the feed-water quickly gives up its heat and condenses, tending to reduce the pressure in the boiler. This reduction of pressure is immediately met and counteracted by the more rapid evaporation of the water in the boiler, all of which is maintained at the boiling point due to the pressure in the boiler. This enforced evaporation of water requires great quantities of heat, which will be taken at the most available point, that is, the point of highest temperature—the heating surface of the boiler. This reduces tne temperature of the heating surface to that of the water in contact with it, and as the water continues to evaporate as long as steam is condensed in the heating of the feed-water, or used for running the engine or any other purpose that tends to reduce the pressure in the boiler, the plates or tubes are maintained at a uniform and much lower temperature than if water below the boiling point were in contact with them, as is the case when the water is fed into the water space of the boiler. We have discovered that boiling water will absorb heat from the heating surface of the boiler more rapidly than water below the boiling point, and this is especially true if the boiling is forced by reduction of pressure, by condensation or otherwise; hence more heat will be taken from the fire and transmitted to the water when acting upon a reducing pressure than when acting upon an increasing pressure, if the water in contact with the heating surface is at the temperature of boiling under that pressure.

These facts were plainly indicated by the results of an experiment in which steam was raised under different conditions and results compared as follows: In raising steam first we noted the pressure and time for each five pounds increase in pressure

Pressure shown by gauge in raising steam from 10 lbs. to 100 lbs. and reducing from 100 to 10.	Time of reading gauge for each 5 lbs. increase of pressure.		Time of reading gauge for each 5 lbs. reduction of pressure with fire drawn.		Revolutions made by engine in reducing pressure each five pounds.	Time of reading gauge in raising steam with engine running.		Revolutions made by engine while raising steam with engine running.	Pressure used by engine in making revolutions in Column F.	Total pressure generated in time E, while engine was running.
A	B		C		D	E		F	G	H
lbs.	min.	sec.	min.	sec.	Revs.	min.	sec.	Revs.	lbs.	lbs.
10	00	00	88	00		00	00			10
15	3	00	73	45	490	2	30	118	1.2	16.2
20	6	00	66	30	452	4	30	142	1.5	22.7
25	7	30	60	30	486	7	30	240	2.5	30.2
30	10	00	57	00	432	9	10	160	1.8	37.0
35	12	00	52	45	450	11	15	226	2 5	44.5
40	14	00	49	30	360	12	40	160	2.2	51.7
45	15	30	46	40	400	15	05	312	3.9	60.6
50	16	30	44	20	340	16	20	172	2.5	68.1
55	18	00	42	00	360	17	40	184	2.6	75.7
60	19	00	40	00	356	19	50	326	4.6	85.3
65	20	35	37	45	384	21	20	240	3.1	93.4
70	21	35	36	20	280	22	25	192	3.4	101.8
75	22	25	35	00	268	24	25	356	6.6	113 4
80	23	10	33	20	312	25	40	240	3.9	122.3
85	24	10	31	50	320	26	50	232	3.6	130.9
90	25	05	30	45	240	28	05	236	4.9	140.8
95	26	05	29	45	100	30	05	444	22.2	178 0
100	27	20	28	20	260	31	10	240	4.6	187.6

from 10 lbs. to 100 lbs. per sq. in., shown in columns *A* and *B* in the accompanying table. The fire was then drawn, the engine started and notes taken on time, pressure and number of revolutions of engine in reducing the pressure each 5 lbs. in going down from 100 lbs. to 10 lbs., as shown in columns *C*, *A* and *D*. Then the steam was raised with the engine running, notes being taken as to time, pressure and number of revolutions of the engine as shown in columns *E*, *A* and *F*. In this way, by correcting for the amount of steam and consequent pressure used by the engine, we obtained the values in column *G*, which are to be added to the pressures shown by the gauge each time, giving the results as shown by column *H* as the pressure which would have been shown by the gauge had no steam been used.

Again, we arranged a glass boiler so that water could be introduced either into pans in the steam space or into the water space in the ordinary way, and found that when cold water was fed into the water space the boiling ceased almost immediately, while it was increased perceptibly when fed into the pans in the steam space. The boiler could be removed entirely from the source of heat and remain until it had ceased to boil for some time, when it would boil rapidly again when feeding cold water into the pans in the steam space.

To more clearly show the increased amount of heat absorbed by the water when it is maintained at the temperature of boiling, we have but to determine the amount of water a boiler will evaporate per hour when the feed-water is introduced at the temperature of the live steam, then calculate the amount of water that would be raised from the freezing to the boiling point by the latent heat of the steam thus produced. Now imagine a boiler containing water at the freezing point equal in amount to the above, and then calculate whether you could heat this body of water to the boiling point in one hour without damage to the boiler by burning or otherwise.

We will leave for future consideration several points relating to boiler explosions, bagged sheets, etc., and will conclude with a brief summary of the benefits to be derived from the use of our apparatus:

1. The feed-water is heated and purified and most of the impurities are removed by blowing off once or twice a day, thus

avoiding the necessity of cleaning the heater as often as would otherwise be necessary.

2. The temperature of the water in the boiler is maintained at a uniform degree, thus reducing the strains from overheating and avoiding the expense of repairs.

3. The saving of fuel which results from the increased absorbtion of heat and the increased steam production possible with a given boiler are items that will assert themselves to all steam users.


ARCHITECTURE

ARCHITECTURAL DEPARTMENT.

CLASSIFICATION OF ARCHITECTURAL STYLES.

PREPARED FOR CLASS IN HISTORY OF ARCHITECTURE BY N. CLIFFORD RICKER, PROFESSOR OF ARCHITECTURE

DIVISION I. EARLY OR ANCIENT.

Group 1. Egyptian. Dates Approximate.

- Section 1. Of Old Kingdom. 3900 to 2340 B. C.
- Section 2. Of Shepherd Kingdom. 2340 to 1829 B. C.
- Section 3. Of New Kingdom. 1829 to 526 B. C.
- Section 4. Of Ptolemaic Kingdom. 323 to 30 B. C.
- Section 5. Of Nubia. 700 B. C. to 100 A. D.

Group 2. Western Asiatic. Dates Approximate.

- Section 1. Babylonian. 2000 to 538 B. C.
- Section 2. Assyrian. 1500 to 606 B. C.
- Section 3. Persian. 559 to 334 B. C.
- Section 4. Sassanian. 226 to 641 A. D.

Group 3. Phoenician and Jewish. Dates Approximate.

- Section 1. Phoenician. 1600 to 146 B. C.
- Section 2. Jewish. 1312 B. C. to 70 A. D.

Group 4. Pelasgian. Dates Approximate.

- Section 1. Of Greece. 1500 to 700 B. C.
- Section 2. Of Asia Minor. 1500 to 550 B. C.
- Section 3. Etruscan. 1000 to 280 B. C.

Group 5. Chinese and Japanese. Dates Approximate.

- Section 1. Chinese. 2350 B. C. to present time.
- Section 2. Japanese. 650 B. C. to present time.

Group 6. Of India.

Section 1. Buddhist. 623 B. C. to 600 A. D.
Section 2. Jaina. 1000 A. D. to present time.
Section 3. Himalayan. 600 to 1200 A. D.
Section 4. Dravidian. 500 A. D. to 1700 A. D.
Section 5. Chalukyan. 950 to 1300 A. D.
Section 6. Indo-Aryan. 700 A. D. to present time.
Section 7. Of Farther India. 500 A. D. to present time.

Group 7. Ancient American. Dates of origin unknown.

Section 1. Mexican. To 1520 A. D.
Section 2. Peruvian. To 1533 A. D.
Section 3. Pueblos and Cliff Dwellings. To present time.

Division II. Classic or Antique.

Group 1. Grecian.

Section 1. Archaic. 700 to 470 B. C.
Section 2. Best. 470 to 338 B. C.
Section 3. Decadence. 338 to 146 B. C.

Group 2. Roman.

Section 1. Archaic. 753 to 200 B. C.
Section 2. Imperial. 200 B. C. to 193 A. D.
Section 3. Decadence. 193 to 476 A. D.

Division III. Early Christian.

Group 1. Of Syria. 250 to 650 A. D.
Group 2. Of North Africa. 250 to 650 A. D.
Group 3. Italian. 200 to 1200 A. D.
Group 4. Of North Europe. 500 to 1000 A. D.

Division IV. Byzantine and Derivatives.

Group 1. Byzantine.

Section 1. Early. 328 to 622 A. D.
Section 2. Neo-Byzantine. 622 to 1453 A. D.

Group 2. Armenian. 622 to 1077 A. D.
Group 3. Bulgarian, etc. 1200 to 1550 A. D.
Group 4. Russian. 964 to present time.

DIVISION V. MOHAMMEDAN.

Group 1. Saracenic.

Section 1. Of Syria. 622 to present time.
Section 2. Of Egypt. 642 to present time.

Group 2. Moorish.

Section 1. Of Spain. 711 to 1492 A. D.
Section 2. Of N. Africa. 642 to present time.
Section 3. Of Sicily.

Group 3. Of India. 975 to present time.

Group 4 Oriental.

Section 1. Of Persia. 641 to present time.
Section 2. Of Turkey. 1200 to present time.

DIVISION VI. ROMANESQUE.

Group 1. Italian. 1000 to 1300 A. D.

Section 1. Of Central Italy.
Section 2. Of Lower Italy and Sicily.
Section 3. Of Venice.
Section 4. Of Northern Italy.

Group 2. French. 1000 to 1140 A. D.

Section 1. Of Southeast France.
Section 2. Of Southwest France.
Section 3. Of Western France.
Section 4. Of Northwest France.

Group 3. British. 1000 to 1177 A. D.

Section 1. Saxon. 1000 to 1066 A. D.
Section 2. Norman. 1066 to 1177 A. D.
Section 3. Scotch. 1000 to 1200 A. D.
Section 4. Irish. 1000 to 1250 A. D.

Group 4. German. 1000 to 1250 A. D.

Section 1. Of Rhine Provinces.
Section 2. Of Northwest Germany and Netherlands.
Section 3. Of Remaining Germany.

Group 5. Scandinavian.

Section 1. Danish. 1025 to 1250 A. D.
Section 2. Swedish. 1100 to 1250 A. D.
Section 3. Norwegian. 1100 to 1250 A. D.

Group 6. Spanish and Portugese. 1060 to 1250 A. D.

Section 1. Spanish.
Section 2. Portugese.

Division VII. Gothic

Group 1. French. 1140 to 1510 A. D.
Section 1. Of Central France.
Section 2. Of Normandy.
Section 3. Of Southern France.

Group 2. Of Netherlands. 1200 to 1530 A. D.

Group 3. British.

Section 1. Early English. 1177 to 1290 A. D.
Section 2. Decorated. 1290 to 1377 A. D.
Section 3. Perpendicular. 1377 to 1550 A. D.
Section 4. Scotch. 1225 to 1550 A. D.

Group 4. German. 1210 to 1550 A. D.

Section 1. Of Germany Proper.
Section 2. Of Austria.
Section 3. Of Northwest Germany.
Section 4. Of Scandinavia.

Group 5. Italian. 1228 to 1440 A. D.

Section 1. Of Northern Italy.
Section 2. Of Central Italy.
Section 3. Of Sicily and Southern Italy.
Section 4. Of Venice.

Group 6. Spanish and Portugese.

Section 1. Early Spanish. 1220 to 1450 A. D.
Section 2. Late Spanish. 1450 to 1575 A. D.
Section 3. Moresco. 1085 to 1492 A. D.
Section 4. Portugese. 1250 to 1575 A. D.

DIVISION VIII. RENAISSANCE.

Group 1. Italian.

Section 1. Early. 1420 to 1500 A. D.
Section 2. Best. 1500 to 1580 A. D.
Section 3. Late or Rococo. 1580 to 1780 A. D.

Group 2. Spanish and Portugese.

Section 1. Plateresque. 1490 to 1550 A. D.
Section 2. Pedantic. 1550 to 1650 A. D.
Section 3. Rococo. 1650 to 1750 A. D.
Section 4. Portugese. 1500 to 1750 A. D.

Group 3. French.

Section 1. Era of Francis I. 1500 to 1560 A. D.
Section 2. Era of Henry IV. 1560 to 1643 A. D.
Section 3. Era of Louis XIV. 1643 to 1792 A. D.

Group 4. English.

Section 1. Elizabethan. 1519 to 1600 A. D.
Section 3. 17th Century. 1600 to 1700 A. D.
Section 3. 18th Century. 1700 to 1800 A. D.

Group 5. German.

Section 1. Early or Best. 1515 to 1570 A. D.
Section 2. Rococo. 1570 to 1800 A. D.

Group 6. Netherlandish. 1530 to 1800 A. D.

Group 7. Scandinavian.

Section 1. Danish. 1600 to 1800 A. D.
Section 2. Swedish and Norwegian. 1550 to 1800 A. D.

Group 8. Russian. 1700 to 1800 A. D.

Group 9. American.

Section 1. English Colonial. 1625 to 1812 A. D.
Section 2. Dutch Colonial. 1615 to 1800 A. D.
Section 3. Spanish Colonial. 1525 to present time.

DIVISION IX. MODERN.

Group 1. Italian Renaissance. 1780 A. D. to present time.

Group 2. Spanish Renaissance. 1750 A. D. to present time.

Group 3. French.

Section 1. Empire, 1800 to 1870 A. D.
Section 2. Revived Classical. 1800 to 1850 A. D.
Section 3. Modern Renaissance. 1800 to present time.
Section 4. Modern Gothic. 1800 to present time.
Section 5. Neo-Grecian. 1850 to present time.

Group 4. English.

Section 1. Revived Grecian. 1800 to 1850 A. D.
Section 2. Modern Gothic. 1825 to present time.
Section 3. Modern Renaissance. 1830 to present time.
Section 4. Queen Anne. 1870 to present time.
Section 5. Modern Jacobean, etc. 1885 to present time.

Group 5. German.

Section 1. Revived Grecian. 1800 to 1875 A. D.
Section 2. Modern Gothic. 1800 to present time.
Section 3. Modern Renaissance. 1800 to present time.

Group 6. Of Netherlands.

Section 1. Modern Renaissance. 1800 to present time.
Section 2. Modern Gothic. 1800 to present time.

Group 7. Scandinavian Renaissance. 1800 to present time

Group 8. Russian.

Section 1. Modern Renaissance. 1800 to present time.
Section 2. Modern Russian. 1850 to present time.

Group 9. Jewish Synagogues. 1450 to present time.

Group 10. Of Central and South America. 1525 to present time.

Group 11. Of United States.

Section 1. Revived Grecian. 1800 to 1860 A. D.
Section 2. Modern Renaissance. 1800 to present time.
Section 3. Modern Gothic. 1825 to present time.
Section 4. Queen Anne. 1875 to present time.
Section 5. Modern Romanesque. 1872 to present time.
Section 6. Modern Colonial. 1885 to present time.
Section 7. Revived Jacobean. 1890 to present time.

LIST OF ARCHITECTURAL MONUMENTS.

COMPRISING THE MOST IMPORTANT EXAMPLES OF THE DIFFERENT HISTORICAL STYLES.

PREPARED FOR THE CLASS IN HISTORY OF ARCHITECTURE, BY N. CLIFFORD RICKER, PROFESSOR OF ARCHITECTURE.

EGYPTIAN.

Daschour, Pyramid of.
Gizeh, Pyramid of Cheops.
The Sphynx.
Karnac, Great Temple at.
Karnac, Temple of Chensu or Khons at.
Karnac, Rhamession at.
Ipsambul, Temples at.
Edfou, Temple at.
Philæ, Temple at.
Meroe, Pyramids at.

BABYLONIAN AND ASSYRIAN.

Koyunjik, Palace at.
Khorsabad, City of.
Khorsabad, Palace at.
Khorsabad, Temple at.

PERSIAN.

Pasagardæ, tomb of Cyrus at.
Naksch-i-Rustam, Tomb of Darius at.
Persepolis, Palaces at.

SASSANIAN.

Firouzabad, Palace at.
Serbistan, Palace at.
Mashita, Palace at.

JEWISH.

Tabernacle, The.
Jerusalem, Temple of Solomon at.
Jerusalem, The Second Temple at.
Jerusalem, Temple of Herod at
Jerusalem, Tombs of the Kings at.
Jerusalem, Tomb of Absalom at

PELASGIAN.

Mycenæ, Lions' Gate at.
Mycanæ, Treasury of Atreus at.

ETRUSCAN.

Cervetri, Tomb of the Seats at.
Cervetere, Regulini-Galeassi Tumulus at.

GRECIAN.

Agrigentum, Temple of Olympian Zeus at.
Pæstum, Temple of Poseidon or Neptune at.
Assos, Temple at.
Egina, Temple of Athene on Island of.
Athens. Temple of Athene or Parthenon at.
Athens, Temple of Theseus at.
Athens, The Propyleum at.
Eleusis, Temple of Demeter or Ceres at.
Bassæ, Temple of Apollo at.
Olympia, Temple of Zeus at.
Athens, Temple of Nike Apteros at.
Athens, The Erechtheium at.
Halicarnassus, Mausoleum at.
Ephesus, Temple of Artemis or Diana at.
Athens, Choragic Monument of Lysicrates at.
Athens, Tower of the Winds at.
Alexandria, City and Monuments at.

ROMAN.

Nimes, Temple at. [Maison carree].
Nimes, Temple of Diana at.
Rome, The Pantheon at.
Tivoli, Temple of Vesta at.
Rome, Flavian Ampitheatre or Coliseum at.

Rome, Circus Maximus at.
Rome, Baths of Caracalla at.
Rome, Triumphal Arch of Titus at.
Rome, Column of Trajan at.
Rome, Tomb of Cecilia Metella near.
Rome, Mausoleum of Hadrian at.
Rome, Palace of Flavian Emperors at.
Pompeii, House of Panza at.
Baalbec, Temple of Helios or Sun-god at.
Rome, Basilica of Constantine or Maxentius at.
Rome, Triumphal Arch of Septimus Severus at.
Rome Triumphal Arch of Constantine at.
Rome, Arch of the Goldsmiths at.
Spalato, Palace of Diocletian at.

EARLY CHRISTIAN.

Kelat Seman, Church of St. Simon Stylites at.
Tourmanin, Church at.
Rome, Church of St Peter at.
Rome, Church of St. Maria Maggiore at.
Rome, Church of St. Paul-without-the-walls near.
Rome, Church of St. Maria-in-Cosmedin at.
Rome, Church of St. Clement at.
Ravenna, Church of St Apollinare-in Classis at.
Ravenna, Tomb of Theodoric at.
Aix-la-Chapelle, Church at.

BYZANTINE.

Ravenna, Church of St. Vitale at.
Constantinople, Church of St. Sophia at. [Mosque].
Ani, Cathedral at.
Moscow, Church of St. Vasili Blanskenoy at.

MOHAMMEDAN.

Mecca, Great Mosque at.
Jerusalem, Sachra Mosque at. [Dome-of-the-Rock].
Cairo, Mosque of Ibn-Toulon at.
Cairo, Mosque of Hassan at.
Cairo, Mosque of Kait Beyat.
Cordova, Mosque at. [Cathedral].
Granada, The Alhambra at.

Seville, Alcazar at.
Bijapur, Tomb of Mahmoud at.
Futtehpore Sikri, Mosque at.
Agra, the Taj Mehal at.
Sultanieh, Tomb at.
Constantinople, Mosque of Suleiman at.
Constantinople, Mosque of Ahmed at.

ROMANESQUE.

Pisa, Cathedral at.
Pisa, Baptistery at.
Pisa, Campanile or Leaning Tower at.
Florence, Baptistery near Cathedral at.
Florence, Church of St. Miniato at.
Palermo, Church of the Materano at.
Palermo, Palatine Chapel at.
Monreale, Cathedral at.
Venice, Church of St. Mark at.
Milan, Church of St. Ambrose at.
Parma, Cathedral at.
Chiaravalle, Church of the Cistercians at.
Pavia, Church of St. Maria del Carmine at.
Clermont, Cathedral of Notre Dame du Port at.
Issoire, Church at.
Tournus, Church of St. Philibert at.
Cluny, Abbey Church at.
Perigueux, Church of St. Frontinus at.
Fontevrault, Abbey Church at.
Poitiers, Church of Notre Dame at.
Poitiers, Cathedral at.
Cæn, Church of St. Etienne or Stephen.
Canterbury, Cathedral at.
London, The Tower.
Durham, Cathedral at.
Cologne, Church of St. Maria-im-Capitol at.
Cologne, Church of the Apostles at.
Cologne, Church of St. Martin's at.
Mayence, Cathedral at.
Spires, Cathedral at.
Worms, Cathedral at.
Schwartz-Rheindorf, Double Church at.

Cologne, Church of St. Gereon at.
Naumburg, Cathedral at.
Bamberg, Cathedral at.
Vienna, Cathedral of St Stephen at.
Drontheim, Cathedral at.
Hitterdal, Church at.
Salamanca, Old Cathedral at.
Avila, Church of St. Vincent at.
Tarragona, Cathedral at.

GOTHIC.

St. Dennis, near Paris, Abbey Church at.
Paris, Cathedral of Notre Dame at.
Bourges, Cathedral at.
Chartres, Cathedral at.
Rheims, Cathedral at.
Amiens, Cathedral at.
Beauvais, Cathedral at.
Paris, the Sainte Chapelle at.
Coutances, Cathedral at.
Rouen, Cathedral at.
Rouen, Abbey Church of St. Ouen at.
Rouen, Church of St. Maclou at.
Rouen, Palais de Justice at.
Alby, Cathedral at.
Mount St. Michel, Abbey and Church at.
Paris, the Old Louvre.
Bourges, House of Jacques Coeur at.
Paris, Hotel Cluny at.
Antwerp, Cathedral at.
Liege, Church of St. Jacques at.
Ypres, Cloth Hall at.
Brussels, Town Hall at.
Canterbury, Cathedral at.
Salisbury, Cathedral at.
Lincoln, Cathedral at.
Ely, Cathedral at.
Westminster, Abbey Church at.
York, Cathedral at.
Westminster, Hall at.
Glasgow, Cathedral at.

Freiberg-im-Breisgau, Cathedral at.
Strasburg, Cathedral at.
Cologne, Cathedral at.
Ulm, Cathedral at.
Vienna, Cathedral of St. Stephen at.
Brunswick, Town Hall at.
Assizi, Church of St. Francis at.
Bologna, Church of St. Petronio at.
Pavia, the Certosa near.
Florence, Cathedral at.
Siena, Cathedral at.
Orvieto, Cathedral at.
Milan, Cathedral at.
Venice, Doge's Palace at.
Venice, Ca d'Oro Palace at.
Burgos, Cathedral at.
Gerona, Cathedral at.
Seville, Cathedral at.
Salamanca, New Cathedral at.

RENAISSANCE.

Florence, Cathedral dome at.
Florence, Riccardi Palace at.
Florence, Strozzi Palace at.
Pavia, Facade of Certosa near.
Crema, Church of Madonna della Croce near.
Venice, Court of Doge's Palace at.
Rome, Cancellaria Palace at.
Rome, Villa Farnesina at.
Florence, Pandolphini Palace at.
Rome, Farnese Palace at.
Venice, Library of St. Mark at.
Rome, Basilica of St. Peter.
Vicenza, Basilica at.
Granada, Cathedral at
The Escurial, Palace of.
Saragossa, Cathedral del Pilan at.
Mafra, Palace at.
Gaillon, Chateau at.
Blois, Chateau at.

Chambord, Chateau at.
Paris, Chateau of Madrid near.
Fontainebleau, Chateau at.
St. Germain-en-Laye, Chateau at.
Chantilly, Chateau at.
Paris, House of Francis I.
Cæn, Church of St. Peter or Pierre at.
Paris, Church of St. Eustache.
Paris, Church of St. Etienne du Mont.
Paris, The Louvre. [Old].
Ecouen, Chateau at.
Anet, Chateau at.
Paris, Palace of the Tuilleries at.
Paris, Palace of the Luxemburg at.
Versailles, Palace at.
Paris, Church of the Invalids.
Paris, Church of St. Genevieve or the Pantheon.
Paris, Church of St. Sulpice.
London, Whitehall Palace at.
London, Cathedral of St. Paul at.
Blenheim Palace.
London, Somerset House at.
Heidelberg, Castle at.
Cologne, Portico of Town Hall at.
Stuttgardt, Neues Lusthaus at.
Munich, Church of St. Michael at.
Dresden, Liebfrauen Church at.
Vienna, Church of St. Carlo Borromeo at.
Berlin, Old Royal Palace at. [Alta Schloss].
Berlin, The Arsenal at.
Dresden, The Zwinger Palace at.
Dresden, The Japanese Palace at.
Antwerp, The Town Hall at.
Amsterdam, The Town Hall at.
Fredericksborg Castle.
Copenhagen, The Exchange at.
Stockholm, Royal Palace at.
Petersburgh, Winter Palace at.

MODERN.

Paris, Arch de l'Etoile.
Paris, Church of the Madelaine.
Paris, the Bourse.
Paris, Arch du Carroussel.
Paris, New Louvre.
Paris, Church St. Vincent de Paul.
Paris, Northern Railway Station.
Paris, Ecole des Beaux-Arts.
Paris, Library of St. Genevieve.
Paris, Hotel de Ville, Old and New.
Paris, Grand Opera House.
Paris, Palace of Justice.
Paris, Church of St. Clotilde.
Paris, the Exhibition Buildings.
Paris, Church on Montmartre.
Paris, Vendome Column.
Paris, July Column.
Paris, National Library.
Paris, Ecole de Medecine.
Lyons, the Bourse.
Marseilles, School of Art.
Brussels, Palace of Justice.
Brussels, the Bourse.
Amsterdam, the Museum.
Petersburg, Cathedral of St. Isaac.
Petersburg, the New Museum.
Milan, Gallery of Victor Emmanuel.
Florence, Cathedral facade.
Berlin, the Theatre.
Berlin, the Opera House.
Berlin, the Bauakademie.
Berlin, the Legislative Palace.
Berlin, the Potsdam Railway Station.
Berlin, the Museum of German Art.
Berlin, the New Synagogue.
Berlin, the Monument of Victory.
Berlin, the Bourse.
Berlin, the Town Hall.
Berlin, the Kaiser Gallerie.

Charlottenberg, the Technische Hochschule.
Munich, the Glyptothek
Munich, the Pinacothek, Old and New.
Munich, the Ruhmeshalle near.
Munich, the Royal Library.
Munich, Church of St. Ludwig.
Munich, the Polytechnic School.
Ratisbon, the Walhalla near.
Dresden, the Court Theatre, Old and New.
Vienna, the Arsenal.
Vienna, the Ring Strasse.
Vienna, the Grand Opera House.
Vienna, the Votive Church.
Vienna, the Town Hall.
Vienna, the Heinrichshofe.
Vienna, the Legislative Palace.
Vienna, the Academy of Art.
Vienna, the Museum of Art and Industry.
Vienna, the University.
London, Bank of England.
London, Church of St. Pancras.
London, the British Museum.
London, Traveller's Club House.
London, Reform Club House.
London, the New Law Courts.
London, the Houses of Parliament.
London, Hyde Park Memorial.
London, the Albert Hall.
London, S. Kensington Museum.
Cambridge, Fitzwilliam Museum.
Oxford, the New Museum.
Liverpool, St. George's Hall.
Manchester, the Town Hall.
Manchester, the Assize Courts.
Washington, the National Capitol.
Washington, the Patent Office.
Washington, the Post Office.
Washington, the Treasury Department.
Washington, the Smithsonian Institution.
Washington, the National Museum.

Washington, the National Library.
Hartford, the State Capitol.
St. Augustine, Hotel Ponce de Leon.
Chicago, Columbian Fair Buildings.
Chicago, the Auditorium.
Chicago, the W. C. T. U. Temple.
Indianapolis, the State Capitol.
Baltimore, the Johns Hopkins Hospital.
Boston, the State Capitol.
Boston, Trinity Church.
Boston, the Public Library.
Boston, the Museum of Fine Arts.
St. Louis, the Museum of Fine Arts.
New York, the Cathedral of St. Patrick
New York, the Cathedral of St John.
New York, the Synagogue Emanuel.
New York, the National Academy of Design.
New York, the City Hall.
New York, the Sun Building. (Projected).
New York, the Lenox Library.
New York, Trinity Church.
New York, Madison Square Garden.
Columbus, the State Capitol.
Philadelphia, Girard College.
Pittsburgh, the Court House.
Philadelphia, the Masonic Temple.
Charlottesville, the University of Virginia.

THE MOLDINGS OF EARLY ARCHITECTURE.

By C. A. Gunn, Class of '92.

A knowledge and appreciation of moldings is one of the essential requirements of a good *draughtsman*.

We might, perhaps, conceive of an *architect*, whose knowledge of moldings was crude, and yet whose appreciation of outlines and proportions of masses, combined with skill in planning, was such that he could originate many good ideas, trusting to others to carry them out successfully. We should, however, as soon expect to find an illiterate man, unable even to spell out his own name, and yet inspired by the grandest of thoughts.

But for the draughtsman, whose sole work consists of putting in definite and accurate form the ideas suggested by his superior, a knowledge of the minor details, and ability to discriminate between the good and bad is indispensable.

It is in the hope of aiding in some slight measure the accomplishment of this end, that the accompanying collection of moldings has been made. They have been collected from various sources, chief among which are the U. of I. collection of architectural illustrations (described in Technograph No. 6) and the works of Perrot and Chipiez.

The Egyptian moldings may be briefly summarized as follows:

1. The astragal or half-round used as the lower member of the cornice.

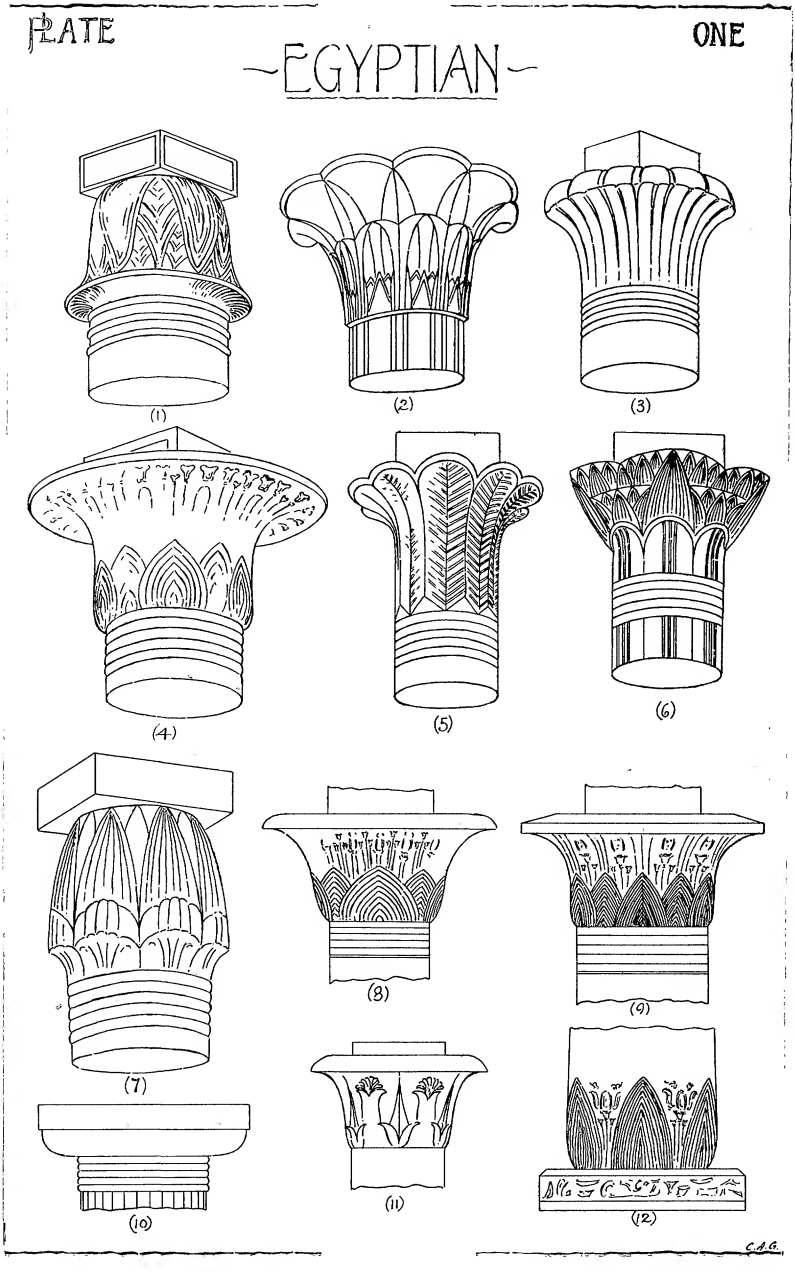
2. The three-quarter-round, with which the exterior angles of the building were finished, mitering at the top with the astragal of the cornice.

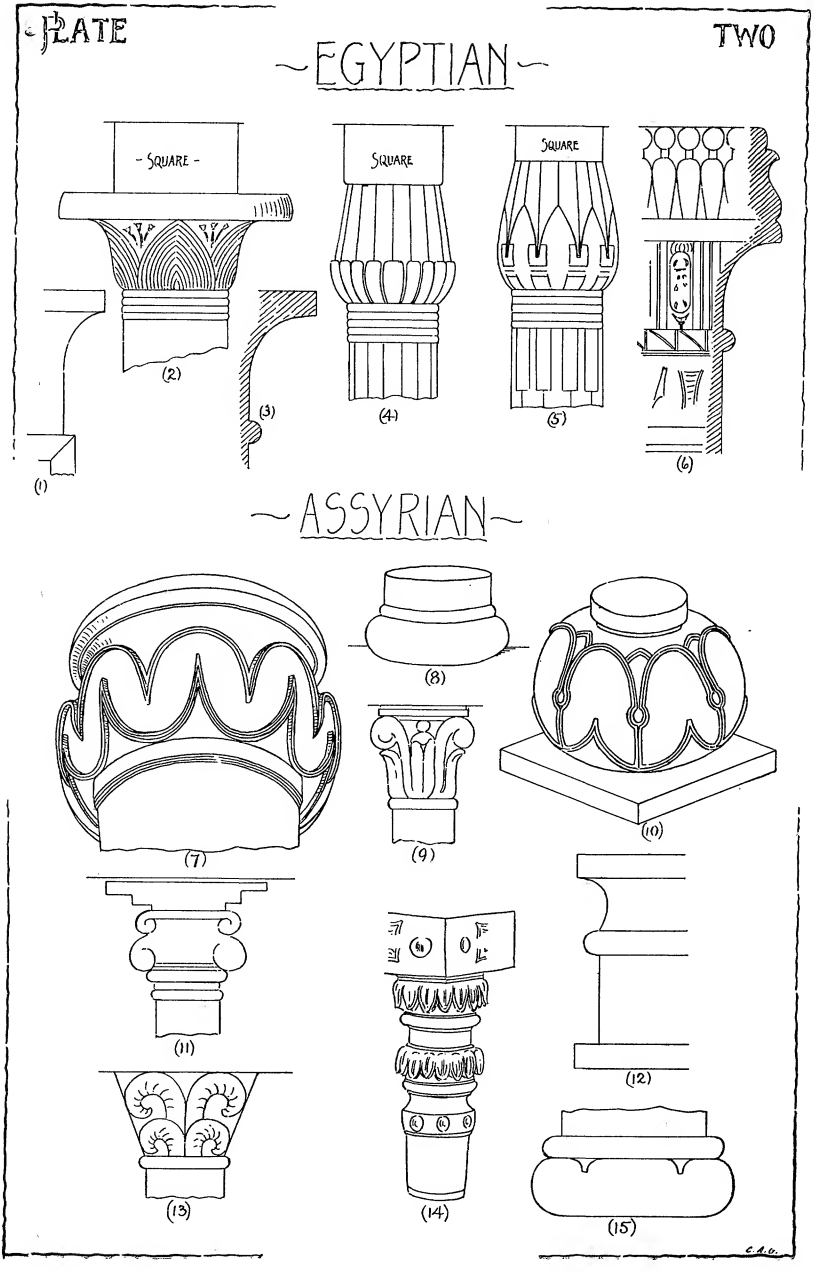
3. The cavetto.

4. The ogee, used on copings of dwarf walls between the front columns of the halls of the Ptolemaic temples.

5. Rings or beads as annular bands encircling the shaft of a clustered or single column.

All of the moldings mentioned above, with the exception of


PLATE ONE
-EGYPTIAN-
(1)
(2)
(3)
(4)
(5)
(6)
(7)
(8)
(9)
(10)
(11)
(12)
C.A.G.


PLATE
TWO
EGYPTIAN
SQUARE
SQUARE
SQUARE
(1)
(2)
(3)
(4)
(5)
(6)
ASSYRIAN
(7)
(8)
(9)
(10)
(11)
(12)
(13)
(14)
(15)

the "ogee," are shown in Plates I and II, together with most of the forms of Egyptian capitals. The cavettos of the cornices—shown in Figures 1 and 3, Plate II—is deep and almost invariably starts at the bottom with a vertical line giving a strong and graceful effect.

As might be expected of a nation which made such an extensive use of brick and clay, the Assyrians had few moldings and those few of no great interest. The capitals in Figures 9, 11 and 13, Plate II, might possibly suggest to our minds the Corinthian and Ionic capitals of the Greek.

In the Persian style we find moldings more extensively used, the cornices being more varied than the Egyptian, as is shown in Figures 4, 5, 6, 7, 10 and 11, Plate III. Most of the cornices, however, were copies of the Egyptian Cavetto, many like 5 and 6 being inferior in that they have not the vertical line at the base of the curve. "Their bases were circular, either composed of a large torus, a cyma reversa decorated by inverted leaves above a plain band, or a single great torus was used, ornamented by shallow horizontal flutes, as in some examples of the Grecian Ionic order.

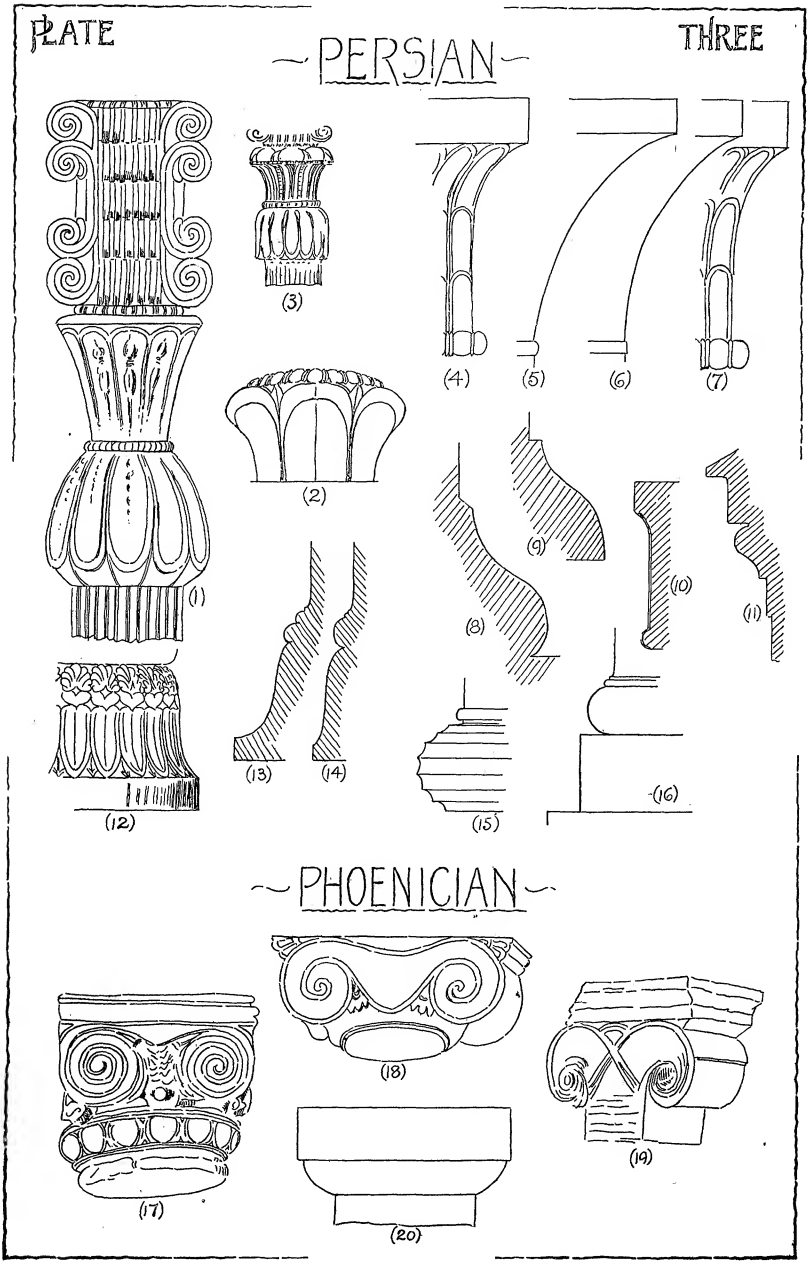
"Two forms of capitals are found, the first consisting of two bulls joined together at the middle, looking in opposite directions, and placed directly on top of the shaft, supporting the end of a ceiling beam upon their joined backs. The other capital is much taller (Fig. 1, Plate III), and is composed of a row of drooping leaves, an expanded bell or calyx, then four groups of volutes, resembling those of the Ionic capital placed on end and doubled, with an upper portion which is now doubtful, but may have been a pair of joined bulls."*

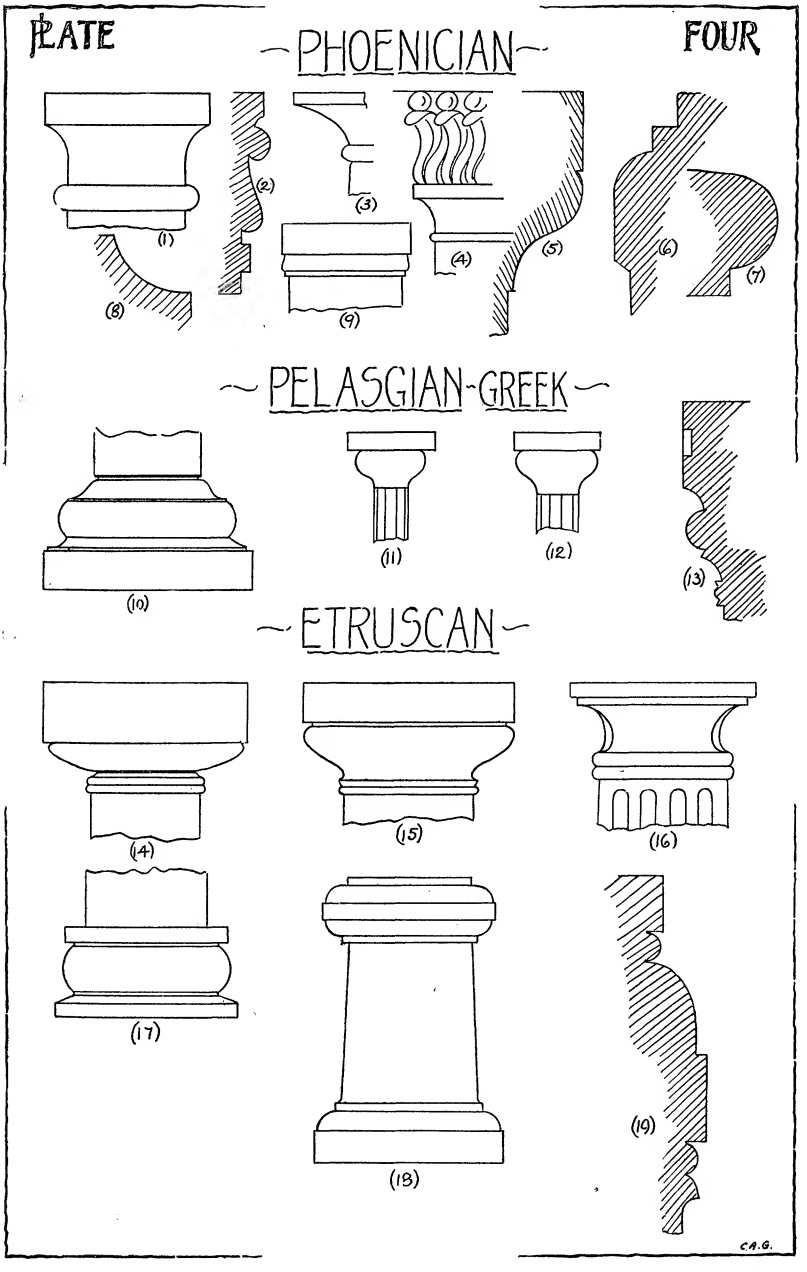
The moldings may be briefly summarized as follows:

1. Shallow cavetto, decorated by leaves.
2. The apophyge between shaft and base of column.
3. The torus, or half-round.
4. The cyma reversa of the base.
5. The volutes of the capital.
6. The dentil band of the cornice.
7. The ogee.

The two extremes of curve of the common form of Persian

*From Prof. Ricker's blue prints on History of Architecture.


PLATE
PERSIAN
THREE
(1)
(2)
(3)
(4)
(5)
(6)
(7)
(8)
(9)
(10)
(11)
(12)
(13)
(14)
(15)
(16)
PHOENICIAN
(17)
(18)
(19)
(20)


PLATE
PHOENICIAN
FOUR
(1)
(2)
(3)
(4)
(5)
(6)
(7)
(8)
(9)
PELASGIAN-GREEK
(10)
(11)
(12)
(13)
ETRUSCAN
(14)
(15)
(16)
(17)
(18)
(19)
C.A.G.

base are shown in Figures 13 and 14, Plate III.

The Phœnician style was largely borrowed in later years from the Greek and Roman, most of the cornices being bad copies of the Egyptian cavetto. The moldings may be briefly summarized as follows:

1. Quarter-round.
2. Half-round, or astragal.
3. Ogee.
4. Cavetto.

The capitals in Plate III strongly suggest the Greek Ionic.

The Greek Pelasgian is chiefly interesting on account of its influence upon early Greek architecture. The section on Plate IV is the column between the lions over the well-known "lion gate" at Mycenæ.

The Etruscan moldings consisted of:

1. Half-round, used on cornices, bases, capitals, etc.
2. Quarter-round, elongated, used on cornices, bases, capitals, etc.
3. Cove, used on cornices, capitals, etc.
4. Bands and fillets, used everywhere.

Columns were rarely employed, and were made of wood. "From a few examples found in tombs, it seems that the column was dimished considerably, without flutes, but with a bad imitation of a Doric capital, and a very ugly base, composed of a great torus between two strongly projecting fillets."*

While there are not, perhaps, many of these moldings that will help us in modern architecture, excepting an occasional use of Egyptian, it is an interesting study to compare the different styles, noting the points of similarity in all.

*From Prof. Ricker's blue prints on History of Architecture.

TALL CHIMNEY CONSTRUCTION.

By J. W. Kennedy, '94.

One of the most important features in connection with a mill or large factory is the design of a tall chimney for the purpose of producing the required draught for the furnaces, and also for conveying the smoke and probably other noxious gases to such a height that they shall not be injurious to the inhabitants of the surrounding locality.

This tall structure does not always present a very pleasing architectural feature, yet it is one of the parts of a factory design that requires special skill and attention, and when neglected is often the cause of an endless amount of trouble, which in many cases is supposed to come from the boilers or furnace.

The designs of this structure is not such a difficult problem as it is often supposed to be, although many of our architects have to refer to some specialist in this line when confronted with such a task, but this is probably from lack of practice as the market is not overstocked with this kind of work. The location of the chimney depends upon circumstances, but should be located as conveniently as possible to all the furnaces. It should not be a part of some other building, but should stand alone upon a foundation of its own, so that when it settles it will not trouble or damage the other building to which it may be attached.

It is quite necessary that the chimney have a good, well proportioned foundation, best made of stone and cement mortar and large enough to spread the load over a sufficient area, so that the ground may not be overloaded. The amount of pressure that can be allowed depends upon the nature of the ground. For clay, about 1½ tons per square foot, and for good sand or gravel as high as 3 tons per square foot may be allowed. A solid rock foundation is to be preferred for a large chimney, when the rock is within a reasonable distance of the surface, but where not, piles may be driven to the rock, and the stone foundation built on these. Concrete, made of broken stone and good cement mor-

tar, is also excellent for foundations. Where bricks are to be used for the foundation of a small chimney, they should be well burnt, and no course, when laid, should project more than 1 inch beyond the course above it.

For a circular chimney the band of the brick work above the foundation, or pedestal, is another important point. The bricks should all show headers on the face of the chimney. For chimneys of large diameter this is done by laying alternate courses of whole and half bricks, but for smaller chimneys this cannot be done, on account of leaving too large a mortar joint on the outside, and probably none inside. This may be obviated by using alternate courses of ⅓ and ⅔ bricks, to that the bricks will lay closer together and with the proper sized joint. The inside face of the chimney may also be bonded in this same way, or, as appearance is no object, the ordinary stretcher and header bound may be used.

In case the flame from the furnaces comes in contact with the lower part of the chimney, it must be protected by a 4 or 8 inch fire-brick lining, running up about one-fifth the height of the chimney.

The chimney generally tapers upward, but this is mostly for appearance, or, since the draught is stronger at the top, it does not require as large an area as at the bottom. The thickness of the walls depends upon the height and diameter of the chimney. For an ordinary size of about 100 feet high, a wall tapering from 17 inches at the bottom to 8 inches at the top, will suffice. A few of the upper courses should be laid in cement mortar, or the chimney may have a stone or cast-iron cap.

Having given the proposed height of a chimney and the horse-power of the boilers for which it is intended, we wish to find the area of the flue. First we must assume some value for the velocity per second of the air in the chimney, or we may find it approximately by the formula

$$V = 6\sqrt{\frac{H\,(T - T')}{491}}$$

in which V is the required velocity in feet per second.

H = height of the chimney in feet.

T = temperature (Fah.) of air in chimney.

T' = temperature (Fah.) of air outside of chimney.

This formula allows about 25 per cent. for retardation owing to friction against the sides of the chimney. The volume of gas per second that is to pass through the chimney may be easily found by allowing 5 pounds of coal burned per horse-power per hour, and 600 cubic feet of gas and smoke from each pound of coal.

$$Q = \tfrac{5}{6}\, H.\ P.$$

Then, if Q = number of cubic feet of smoke to be disposed of per second. At a temperature of about 500° F., volume increases with temperature. If A = area of chimney in square feet, and V = velocity of smoke per second, then

$$A = \frac{Q}{V}$$

which is the required area of the flue.

The chimney should be high enough to produce a velocity of about 12 feet per second, in order that the draught may not be checked by the winds. Accelerating coils, which may be supplied with exhaust steam, are often placed at the bottom of the chimney to increase the velocity of the air. When the area of a chimney is too great for the furnace, there is not sufficient heat in the smoke to warm the air enough to produce an upward current or draught, and smoky chimneys are the result.

Next, it is necessary to investigate the liability of the chimney to be overturned by the wind. For a square chimney, the maximum pressure equals the product of the wind pressure per square feet, by the area of one side of the chimney in square feet; for an octagonal chimney three-fourths of this amount, and for a circular chimney one-half this amount, or half the diametral section by the pressure. Then the force tending to overthrow the chimney is equal to this total pressure into the distance that the centre of gravity, of that part considered is above the joint under consideration. The resisting force is equal to the weight in tons, into the distance from the vertical axis of the chimney to the outside of the joint under consideration.

Let P = wind pressure in pounds per square foot on vertical surface.

Let X = distance from axis of chimney to outside of joint considered.

Let Y = distance from joint to the resultant of wind pressure.

Let A = area exposed to wind.

Let W = weight of chimney above joint in tons. Then $W X$ = resisting moment in foot tons, and $\frac{A P Y}{2000}$ = force tending to overthrow the chimney in foot tons. When the chimney is about to overturn, these two forces must be equal and we have

$W X = \frac{A P Y}{2000}$, or $P = \frac{W X 2000}{A Y}$ = force necessary to overturn the chimney.

This formula should be applied to each joint, and should any joint give a result of about 50 pounds, the chimney is unsafe, as the maximum wind pressure may sometimes exceed this value, but for values of P equal to 90 or 100, the chimney may be considered perfectly safe.

During the construction of a chimney, great care should be taken to see that it is built up vertically. If the foundations have not an equal bearing, the chimney is apt to settle to one side. It is always an excellent plan to complete the foundation several months before the brick shaft is started, and when finally started not more than five or six feet should be laid up per day, in order to give the mortar time to set. A chimney that is found to lean from the vertical may be straightened by sawing in at several of the lower joints on the side from which the chimney leans.

APARTMENT HOUSES.

By Charles W. Noble, '95, Architectural Course.

This title, or one very similar, has graced many articles in various periodicals during the past few years. These articles have been of more or less merit and interest, varying with the purpose of the author and his particular view of the subject.

From an architect's standpoint, however, it may be said that little of value is to be found in a condensed form, so that a student is at quite a disadvantage in obtaining accurate or useful information concerning this class of buildings. It becomes necessary, in studying the subject, to examine many volumes of both American and foreign works on Architecture, and to take from each such material as relates to the subject; for, so far as I know, there is not any complete work devoted to this subject alone, though certainly it contains material enough to form one.

Many persons consider apartment houses as having been devised in recent years, but such is not the case, for the study of Roman Architecture shows them to have been known to the Romans and used by them to such extent that laws were enacted which related to them, and one of these laws governed the height of such structures.

During the Middle ages the majority of the people in all the large cities of Europe are said to have lived in such houses. The fact that, for the most part, the common people were practically enslaved,—the nobility owning all land, and owners, then as now building for revenue—and, further, the extent of the city wall, (an important thing in the matter of its defense, and all cities were then thus fortified), demanded a compact arrangement of habitations.

No accurate description of the arrangement of Roman houses has come down to us; but from such matter as is recorded, it may

be inferred, without serious error, that the rooms were small, low and dingy.

The arrangement of the houses of the Middle Ages is better known, for some few examples of this type are still to be found in the dead cities of southern Europe, where six and seven story buildings on narrow lots, and even narrower streets, are most commonly met with.

To the architect, however, the plans of these structures are of little interest, for they furnish no suggestions or arrangements which would be in any way applicable to modern buildings; but they do, in a great measure, explain the prevalence of the plagues of this era, for they are simply dark and filthy honey-combs for the habitation of man.

In many countries of Europe at the present day the greater part of the population in the cities lives in apartment houses, and in this country they are taking a prominent place as the residence of the majority of people who find it necessary to live close to the business districts of large cities.

This type of building met its earliest and greatest development in France where, for many years, architects have studied for its improvement more diligently than has been done anywhere else. About the middle of the present century this development became quite marked and has progressed steadily since until, at the present time, there are to be found no better planned apartments in the world than are in Paris, and those of equal merit are, for the most part, copies from French originals, of which there are many in this country.

These buildings are now, in all countries where used, erected as investments; and to arrange the plan so as to obtain the most favorable disposition of rooms at as low cost as is consistent is a fundamental principle with all designers.

National customs, local preferences, and varying building laws, so materially affect the plans of different nations, however, as to render comparison a matter of much difficulty.

Cosmopolitan American cities offer favorable opportunities for the introduction of any of the good features, or any combination of such, from foreign plans; and the appreciation of the American people for well planned apartments is shown by the great number of such buildings in all the larger cities. The popularity of these buildings is rapidly increasing.

French Designs.

The Apartment Houses of Paris, especially those of late date, are for various reasons the best examples for American designers to study; but the great irregularity of many Paris building sites—made so by acute and obtuse intersection of streets—renders many of the arrangements suitable for special cases only.

The court yard is an interesting and important part of a French house. Architecturally it is always decorated as the street front is, and the enclosed area is arranged in walks, grass plots, and flower beds, in the case of larger ones, and is decorated with potted plants and shrubs in smaller ones.

These courts are in charge of the janitor, whose special duty it is to keep the plants, grass, and walks, in good condition.

A driveway or carriage entrance from the street is arranged in most of these courts, even in the smaller houses, for it is from the court that entrance is had to the vestibules and to the stairways leading to the upper stories, this arrangement being considered preferable to entrance from the street as is arranged in the buildings in most other countries.

Carriage stables have in some cases been provided at the rear of the courtyard and, while this is no doubt a convenience, it can hardly be favored for use in American houses of this class; though it has been used with apparent success in some of the finer city residences in Washington and Chicago.

The plan of the upper stories of a small apartment house in Paris is shown in Figure 1. In this house there are two separate apartments on each floor, each being reached by a separate stairway leading from a vestibule opening into the court, which latter has a carriage driveway leading to the street. In all cases of enclosed courts this driveway aids in creating a thorough circulation of air, the absence of which forms the principal objection to the use of such courts.

The stairways, as may be seen, are well lighted—a characteristic and a very good feature of French houses.

An entrance hall or private vestibule—an almost indispensable part of a French apartment, opens off each stairway landing and serves as a means of access and connection to the various rooms.

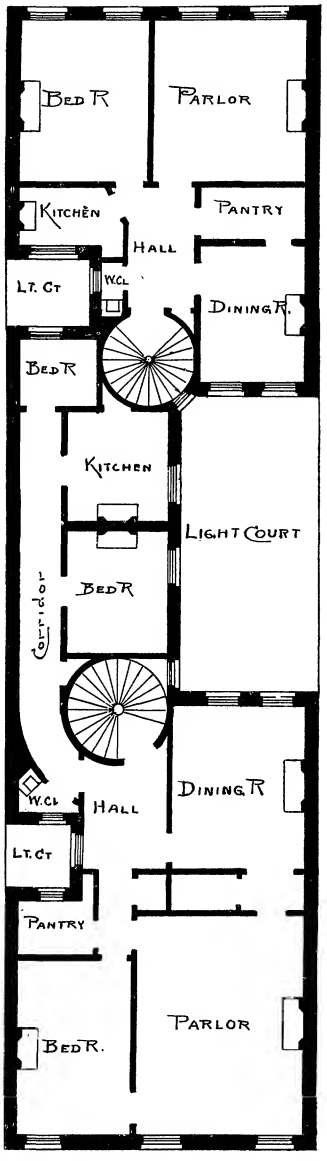


FIG. 1. Plan of Upper Stories of an Apartment House in Paris.
From *Calliats "Parallele."*

The arrangement of the rooms with relation to each other is quite favorable, though not entirely in accordance with modern ideas. A small kitchen separated from the dining room, and a large pantry in connection with it, is the French house-keeper's ideal.

A service or servant's stairway has been omitted from this plan, but such is usually provided and is generally so disposed as to serve two or more kitchens on each floor.

Figure No. 2 is the plan of an earlier building, this one having been erected in Paris in 1858, and is six stories in height. In this case also, there are two apartments on each floor, and the principal stairways, the vestibules, and the light courts are very similar to these same features in the previous plan A single service stairway, convenient to the kitchens, and having a separate entrance from the court, is here added.

The stairway to the front apartment is lighted by a skylight, but, because of the height of the building, the lower stories are quite dark, and this may also be said in regard to the servant's stairway, which is lighted from the small enclosed court that serves the rear kitchen

All the other rooms, however, are well lighted and ventilated, with the exception of the water closets, which are supposed to receive both light and air from chimney like light shafts with which they are connected. The non-effectiveness of such arrangement is now so fully realized that it is seldom employed in modern work.

The plan of having rooms open into other living rooms, instead, instead of into halls, is also seldom used now, but is found in this and other buildings of the same period.

The closets, it will be noticed, in both cases, are not very numerous or well located, and I do not know how serious a defect Frenchmen consider this to be.

On the whole, however, these may be considered very successful plans, and fair examples of designs executed in 1860 and I have never found any executed in other countries at about the same time that in any way equal them; many, in fact, of later designs of other countries are much their inferior.

The very best class of French people live in apartment houses, and their being very much inclined to sociability has

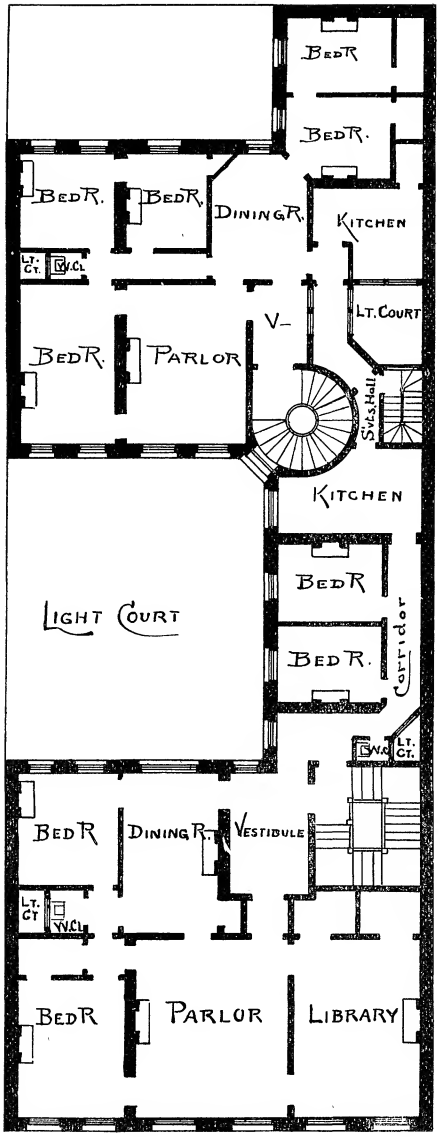


Fig. 2. Plan of Upper Stories of an Apartment House in Paris.
From *Traite d'Architecture, Vol. 2.*

caused the apartment house, in many cases, to develop into a coöperative household or private hotel, such as have been used in this country in late years.

Whole squares are often occupied by a single apartment house in Paris, and these houses are designed and finished throughout with a view to providing for the comfort and convenience of the occupants, and that, in these respects, the designs are successful is attested by the fact that they so often are, and long have been, copied after.

The "Dakota" and "Vancolear" apartment houses in New York, and the "Hotel Hamilton" in Boston, are good examples of American adaptations of French plans; the first one having even the inner court, the vestibules, and stairways arranged just as is found in France, except that an improvement in the way of a sub-surface courtyard for the use of tradesmen's vehicles is provided; and it is from this that all the freight elevators and service stairways lead to the upper stories. Thus the main courtyard is reserved for the exclusive use of the tenants with their fashionable equipages.

German Designs.

In a few points German apartment houses resemble, but in no way do they equal, the same class of buildings in France.

This is strange too, for in most works of architecture the Germans cannot be said to be behind, and in some cases they are in the lead of other nations.

This style of design is by no means new in Germany; it has, however, long remained in an undeveloped state, but at present may be said to be rapidly improving.

In early buildings small and enclosed light courts and poorly arranged and incompletely separated suites, having dark stairways, halls and rooms, are quite the rule; but in many houses lately erected these defects have in a great measure been avoided.

The houses of this class erected in Prussia have the suites more poorly arranged, as a rule, than is found in any other part of the empire; for Prussian architects seem never to consider a private hall or passage to the various rooms as being a necessity, and therefore a Prussian apartment is but a collection of rooms of which each one, excepting the last, forms a passage to the succeeding.

Figure 3 is the plan of a house in Buda Pesth and, though it is not a very recent design, it is a good example of how Germans arrange their buildings with a central court.

The open gallery, which extends entirely around the court and is so suggestive of the plan of a Florentine palace, furnishes the only means of access to the various apartments, of which there are nine in the plan here shown.

The living rooms are lighted either from the street or court; but in the case of the water closets and bath rooms the light and

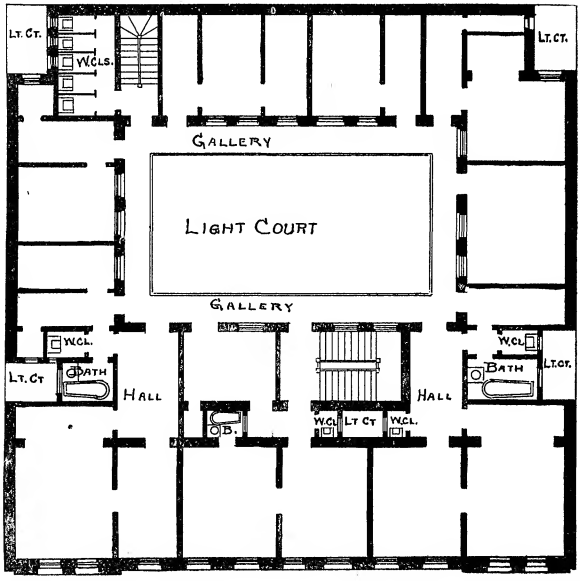


FIG. 3. Plan of Upper Stories of an Apartment House in Buda Pesth. From *Handbuch der Architecture.*

ventilation is insufficient, as the small courts are inadequate. In the case of the rear apartments these closets are most inconveniently arranged, they being grouped in a single room and entirely separated from the suite to which each belongs.

This type of gallery arrangement has been used in some American hotels and in office buildings, in which cases the court is roofed with glass, but it offers no advantages for apartment houses.

An improved plan, having but a single apartment on each floor, is shown in Figure 4.

The locations of the front bed room, the study, and the kitchen, with relation to the other rooms, are not among its best features. The lighting and ventilating of all the rooms and

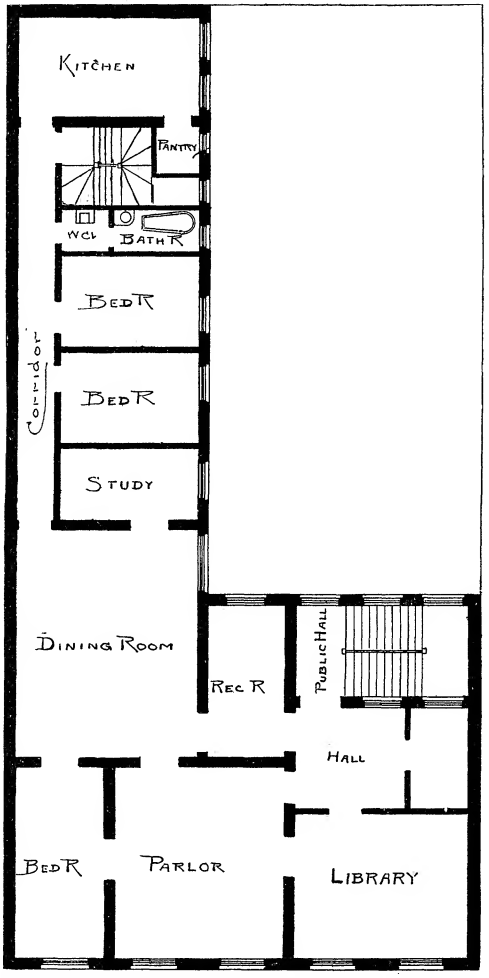


FIG. 4. Plan of Upper Stories of an Apartment House in Berlin. From *The Builder*.

stairways is amply provided for, and these things seem to be the only points considered in arranging the rooms.

Figure 5 is a plan very similar to Figure 4, and shows the arrangement of a house in Breslau.

The kitchen and the study are each in better relation to the other rooms, but the bed rooms remain the same. In this case also every room and both stairways are well lighted. A servant's bed room and a small store room are arranged in the space

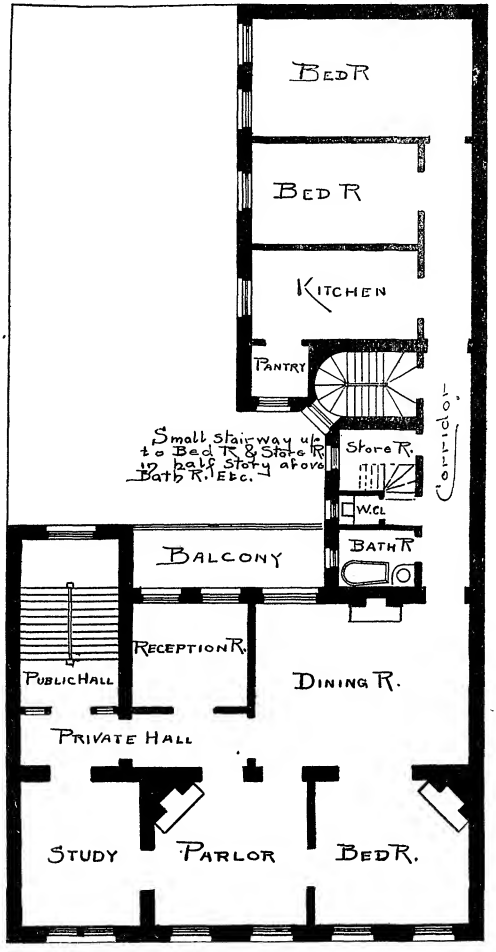


FIG. 5. Plan of Upper Stories of an Apartment House in Breslau. From *Skizzen Buch*, 1883.

above the bath room, and this can be done in German houses, as the ceilings are seldom less than fourteen, and usually from sixteen to eighteen, feet in height.

This seems an excessive height and in America would tend to make the rooms look very awkward, giving many of them the proportion of a brick set on end.

In each of the houses shown in Figures 3, 4 and 5, there is an open passageway leading from the street to the courtyard, and it is from this passage that the main stairway leads to the upper stories—the rear stairway only leading directly from the courtyard.

In many German cities the building regulations, which are strictly enforced, govern the width of the passage, and some require that it be sufficiently large to permit of the entrance of fire engines to the court. The area of the court is also regulated, and this fact, no doubt, accounts for the absence of small courts from late German plans; but while it accomplishes a very good end in compelling a well lighted suite, it is the cause, in a measure, of the awkwardness of the arrangement found in so many examples.

In Figure 6, a house which was erected a few years ago in Cologne, there is no improvement shown. A small enclosed court is supposed to light the public hall and stairway, and also the private hall. The dining room is here, as in Figures 4 and 5, made to serve as a connecting link between the front and rear parts of the suite. The rear stairway leads from the courtyard, which in this case is not provided with a passage to the street. This stairway is much better lighted than is the main one.

The entire absence of closets from these plans is considered, by American designers, to be a most serious defect. And in many cases not even a pantry or a store room is provided.

On the whole, a German apartment house may be said to furnish but a poor subject for a student of architecture, for it seldom has arrangements or suggestions which are available in modern American work.

English Designs.

The concluding paragraph on German examples, will also apply to the English with but slight modification, if in fact any is necessary.

Apartments have not been in favor in England as long as they have in other countries, and indeed at the present time

there is said to be small demand for them; the English people seemingly having a prejudice against living in houses common to two or more families, and placing their trust preferably in vertical walls. Whatever the case may be, however, it does not matter much; though certainly such prejudice would aid much in hindering the development of houses providing horizontal in place of vertical diaphrams between the various occupants.

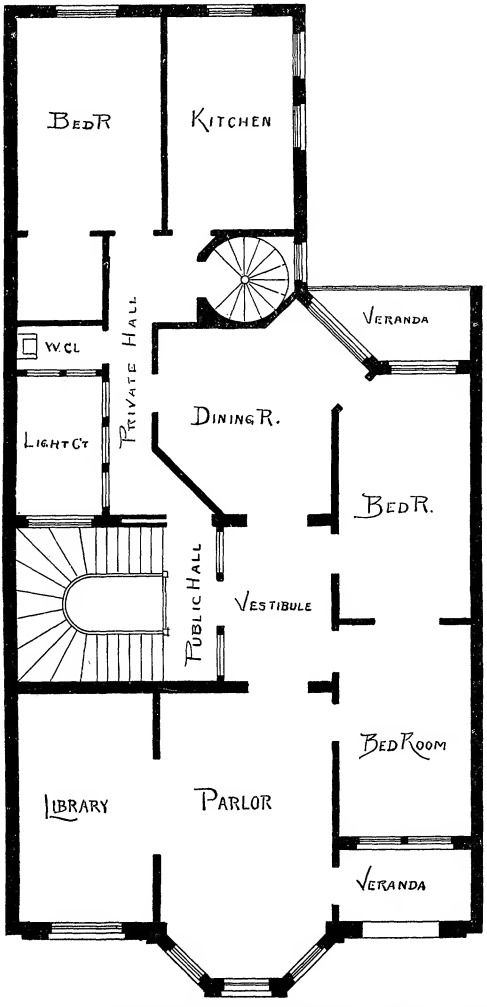


FIG. 6. Plan of Upper Stories of an Apartment House in Cologne. From *Bulletin de la Societe des Architects et Ingenieurs Hanover.*

Such examples as do exist, and these are principally in London, show no improvement over the work of other nations, with the exception of a few cases where the "Duplex System" has been used to good advantage.

Light courts of small area and enclosed courts are not often used, and, as a rule, all rooms in English apartments are well lighted and ventilated, but the arrangement of the rooms with relation to each other and their respective uses is seldom commendable, though usually a corridor connecting these is provided.

Figure 7 is the one-third plan of a block of so-called "mansions" of the English type. This is a six story building and is provided with an elevator, a luxury in England even in the best of houses.

The public hall, containing the elevator and stairway, is well arranged to serve two apartments on each floor and this with the light and ventilation to all rooms are the only good features of the plan.

A rear stairway finds a substitute and certainly a poor one in a dumb waiter.

The corridor is too long and dark and the grouping of the main rooms is not compact enough to warrant the arrangement being considered a good one; the kitchen and dining room in particular are on too distant terms for such closely related functions as each has to perform. The location of the bath room is however a good one, with regard to the others and especially with regard to the bath rooms.

The sculleries and pantries are evidently ample, but the lack of closets is very marked, especially in the bed rooms; and such is generally the case in England as in other foreign countries.

Another example of what is found in England is shown by Figure 8, the half-plan of another London house. This one is five stories high, and though intended for the better class of tenants, is without an elevator. It has but a single stairway leading to the upper floors, and this, as well as every room, is well lighted without the use of courts for the building, being but two rooms in depth—an uncommon thing in this class of houses—does not demand these.

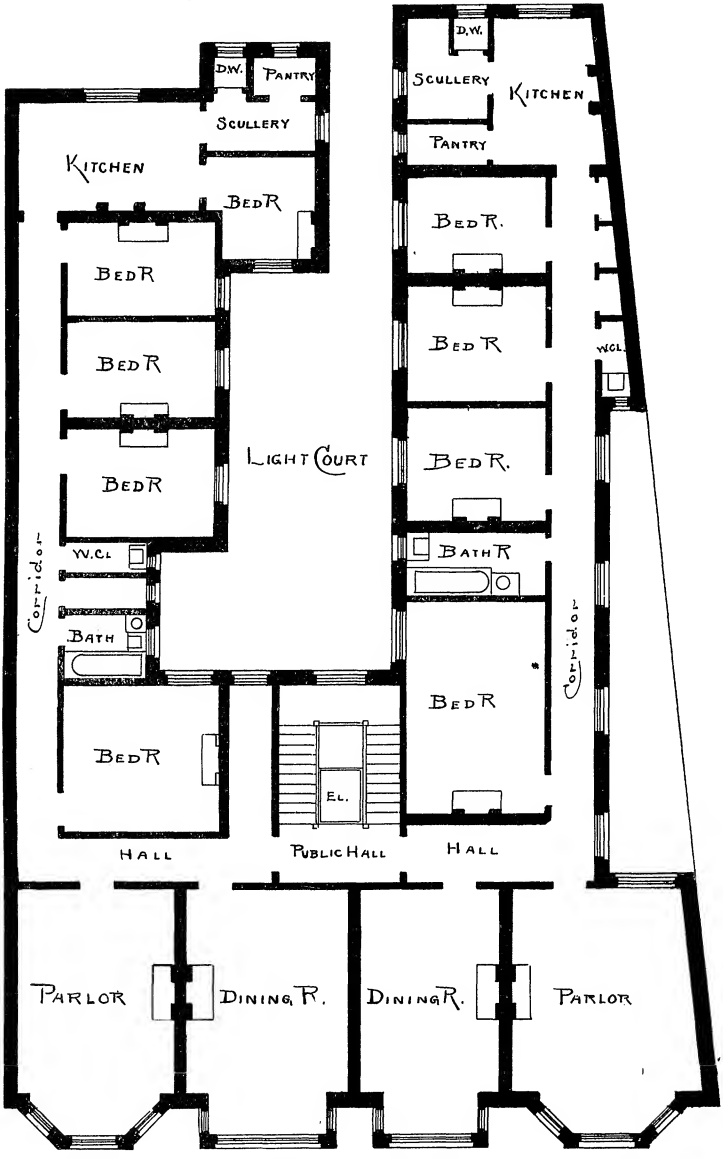


FIG. 7. Plan of Upper Stories of an Apartment House in London. From *The Builder*.

The arrangement of the rooms, and especially those in the right-hand apartment, is no better than in the preceding plan, though they do not number as many nor are the corridors as long, for the principal ones are too distant from the entrance to the suite, thus making it necessary in reaching these rooms to pass by the doors opening into all the others; especially is this objectionable with regard to the water closet and bath room doors, which two are the first ones met on entering the corridor.

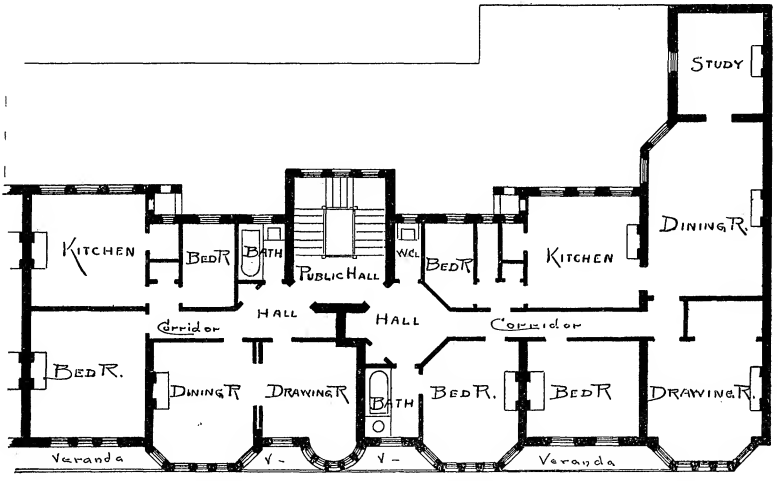


FIG. 8. Plan of Upper Stories of an Apartment House in London. From *The Builder.*

The dining rooms and kitchens are arranged in better connection than in Figure 7, and the bed and bath rooms are in close connection; but the latter, as before suggested, is in the worst position regarding publicity in which it could be arranged.

An Englishman who has written on the subject of apartment houses, states that those of America are far superior to any he has found elsewhere, but he gives no reasons for the usual awkwardness of the English arrangement, nor does he speak of advantages of any sort as being possessed by an English plan.

AMERICAN DESIGNS.

American apartments are in many respects peculiar to America, while many of this class of buildings show arrangements peculiar to certain foreign countries, and particularly is

this noticeable when the arrangement is a poor one. These latter facts are explained by a reference to a directory of our architects, where it will be seen that many of them are foreigners and, of course, as experience in the matter has often shown, their designs retain the peculiarities—good or bad—of the country in which they received their education. This is not invariably the case, however, for I have seen French architects, here in America, design houses which would disgrace a Tartar; though, as a rule, French designs are good ones.

It does not require an old man to remember when this class of building first attracted attention in this country, and, indeed, the designer of the first one I have ever seen a record of is still a practicing architect in New York, and bears a national reputation.*

Since their introduction these buildings have been rapidly developed and are now in great favor in all large cities. The introduction itself was the result of efforts to adapt our mode of living to the requirements of the day; and it is certainly a great reform in our domestic architecture, the necessity of which was fully recognized throughout the East.

Before regularly planned apartments were erected in our larger cities, it was customary for families of limited means to take up residence in the abandoned city mansions of the richer class, where each would occupy a few rooms. These buildings were, of course, most unsuitable for such use, but there was little or no choice in the matter; for a single dwelling house, at a reasonable cost and in a convenient location, was not to be had.

An apartment house occupying the same ground as is required for a residence gives accommodation for many more families, thus offering greater returns to investors; and it is mainly this that accounts for the dark, unventilated rooms and awkwark arrangement of early plans; for the number of rooms and not their wholesomeness or arrangement was the thing considered.

The first successful designs on a large scale were those of houses erected in Boston, and these were soon copied in New York. These buildings were termed "French Flats"—and quite appropriately so, for many of them were almost direct copies from French originals.

*R. M. Hunt, Architect. Building was erected in 1856.

In a criticism of these early plans there is little of good to be found, when viewed in the light of the present day on the matter of apartment designing. The absence of adequate provision for lighting and ventilating the various rooms is the most serious defect found, and this exists in many late as well as early designs, even in cities where boards of health and building regulations make pretense of providing against such abominations. Private halls or corridors are also too often omitted and a single stairway is frequently made to answer as both main and service stairway, without even so much as the addition of a dumb waiter.

American designers have always recognized the necessity of having one or more of the main rooms of an apartment fronting upon the street and, with the exception of France, this arrangement is usually the one used in foreign houses; and even the French use it when convenient, but do not insist upon having it.

Entrance to the main stairway is almost invariably through a vestibule or short hall leading from the street, there being, in this country, but few examples of the French plan of entering houses from the court. The "Dakota," in New York, is, as before mentioned, a notable exception.

Figure 9 shows the plan used for a block of four story apartment buildings in New York City. The general arrangement is such as is very common in all American cities. Small courts—much too small—are used as a means of lighting and ventilating the bed rooms, halls, and bath room, but, as the adjoining building transforms these into enclosed courts, the upper floor is the only one which receives any benefit from them. These courts are of brick work, as required by law in New York and in most other cities.

A single stairway in each separate building is all that is provided, a dumb waiter—a very poor substitute being made to serve the purpose of a service stairs. In buildings of this character it is usually best to have the main rooms—parlor and dining room—in closer connection than these rooms are in this case, though it is evidently for the purpose of securing light in each that they are here planned at such distances from each other.

The bath room is well placed with regard to the rear bed rooms, but to reach it from the front bed room in privacy, is not

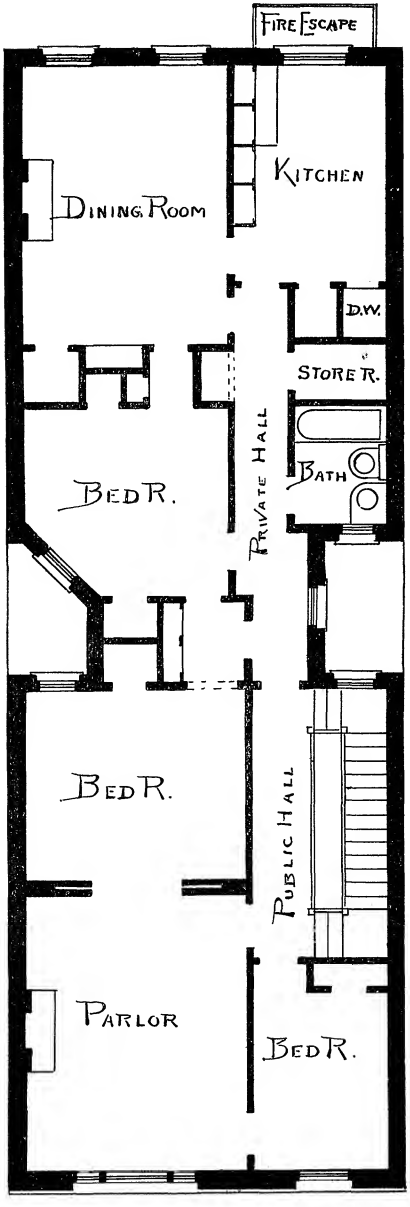


FIG. 9. Plan of Upper Stories of an Apartment House in New York, N. Y.

provided for. Closets are numerous but rather small and a niche in the rear hall is provided for a refrigerator, which provision is too often neglected.

The connection between the front and rear rooms of the apartment is very poorly made, it being necessary to pass either through a bed room or the public hall in going from the parlor to the rear part.

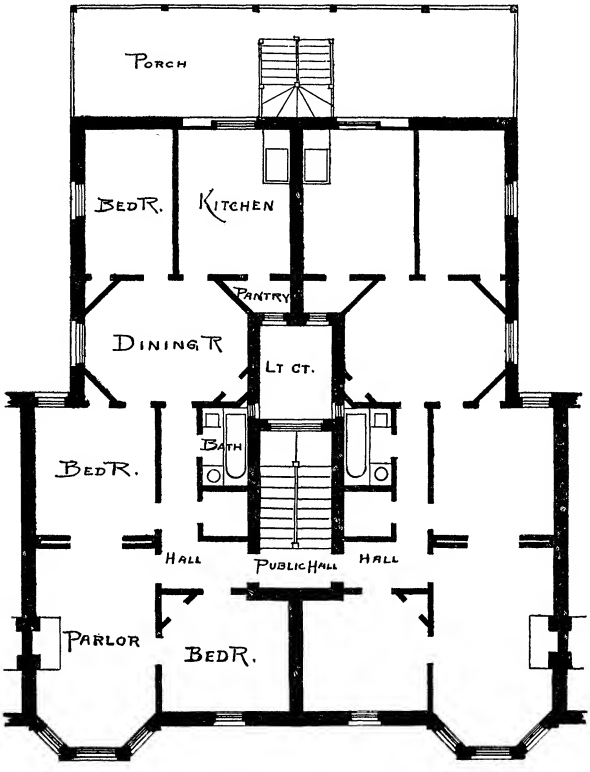


FIG. 10. Plan of Upper Stories of an Apartment House in Chicago, Ill.

A better general arrangement on even less space is shown in Figure 10. This plan shows a style closely followed in many Chicago houses. The small court is here employed also, but not in connection with any living room, these being lighted from the street or from a large court which is entirely open at the rear.

The front stairway and hall show economy of space in arrangement and are better lighted than in the last case, the first story having light through a glazed doorway of the same width as the stair hall. The rear stairway is on the outside of the building and protected from the weather by a roof extending over the rear porch.

The grouping of the rooms is quite satisfactory, all being in connection with the private hallway with the exception of two in the rear; of these, however, it is best not to have the kitchen

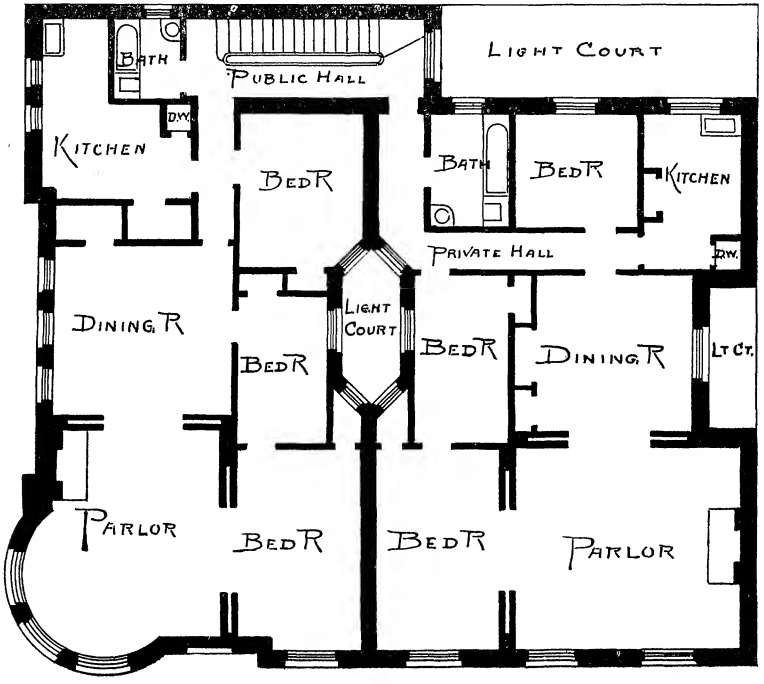


FIG. 11. Plan of Upper Stories of an Apartment House in New York, N. Y.

so connected when a rear stairway is provided, and the other being the servant's room it is the one in which inconveniences can best be tolerated. Closets are provided in each bed room and though rather small they are better than none.

Figure 11 is a good example of as poor planning as often finds space in American architectural journals. This represents

the arrangement used in a building five stories high in a good neighborhood in New York.

This being a corner plan it presented special advantages for good designing, but the way these advantages were disregarded is a disgrace to the profession, as this is the work of one who claims to be an architect. The first story is arranged in two stores and the other floors are as here shown.

The enclosed courts, upon which many of the rooms depend for light and ventilation, are much too small and the only stairway in the building is placed in the most inconvenient position imaginable—at the extreme rear of each apartment.

To reach the parlors, from this stairway and from the public hall, it is necessary to pass by kitchen, bath and bed room doors, and through the dining room and, upon reaching it, it is found to be out of all proportion to the other rooms of the house.

The bath rooms could not have been located in more inconvenient positions. The one opening from the main hall is arranged in violation of common decency and the other is placed too close to the entrance to the private hall. The dumb waiters ara not sufficient for all the purposes of a service stairway, and therefore the main stairway must serve for many objectionable uses. Closets, and pantries unworthy of the name, are found in the various rooms, but are too small to be of much account.

On the whole either apartment could hardly have been worse and, were it not for the fact that many good examples, which were erected in the same year,—1887—can be found, one might think that American apartment designing was a lost art at that time.

Figure 12 shows plan of a corner apartment house in Minneapolis and, with regard to the number of irregularly shaped rooms on a rectangular site, it is rare specimen.

In this there are five suites on a floor; that in the center consisting of but two rooms, and being practically a bachelor apartment; the rest being fully equipped as six room flats.

Two of the light courts are upon the lot line, and so long as there is no building on the adjoining space these will be of service; the rest are open to the street.

The main stairway, which is reached through a wide and well lighted hallway from the street, and the public hallway are

well arranged to serve all apartments on each floor. The service stairways, which have access to the street through basement hallways, are well connected with the kitchens but are dark on the lower stories. The system here employed, of light-

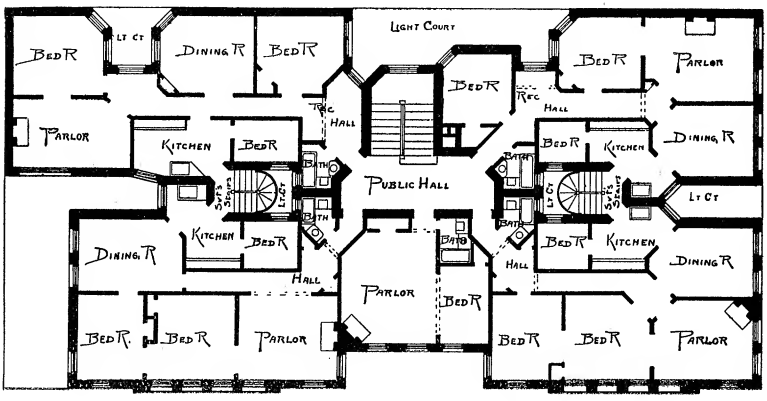


FIG. 12. Plan of Upper Stories of an Apartment House in Minneapolis, Minn.

ing the bath and bed rooms by means of what is practically the well hole of the stairway, is hardly commendable though often used. The skylights at the roof, protecting the stairways from the weather, assures a poor circulation of air in the courts.

The parlors being placed in such positions as to command a view of the street necessitates, in these suites, too long a passage between the public hall and these rooms. The dining rooms and kitchen are in close connection, but china closets and pantries are lacking in these—a few rows of shelving on the kitchen walls being substituted. The positions of the bath rooms, though these are accessible from the main bed rooms, are the most disadvantageous to be found; for these rooms open directly from the reception hall and close to the entrance door of the apartment.

Figure 13 shows the arrangement of a four story apartment house in Chicago, erected in 1887. Light is well provided for in all rooms, for this, too, is a corner building and has only the minor rooms arranged around the court.

The main and service stairways are each well arranged with

relation to the suites, of which there are two on a floor and every room of which is accessible from the private hall.

Bay Windows are not as numerous in designs of the present day as here shown, for the regulations in most cities are averse

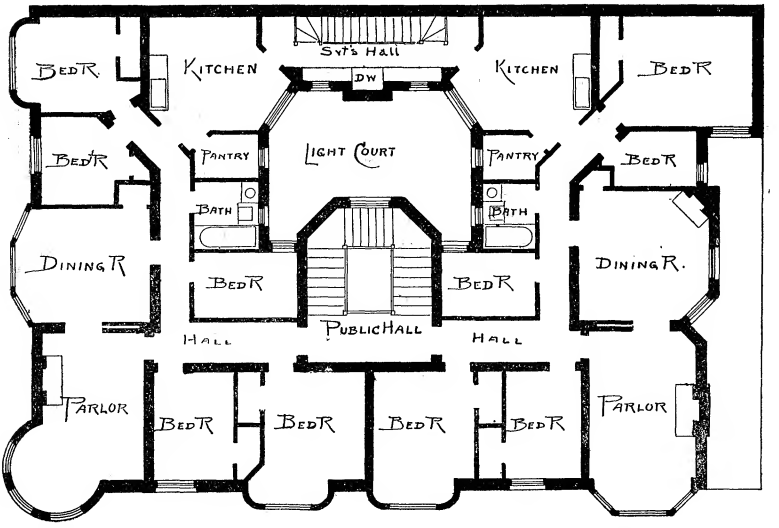


FIG. 13. Plan of Upper Stories of an Apartment House in Chicago, Ill.

to them, even to prohibiting their use entirely, in a few instances.

With but one exception the buildings so far illustrated have not been provided with elevators. The exception being an English house shown in Figure 7, which, by the way, is provided with one of American design and manufacture.

The height to which these buildings are now carried, however, renders these devices an actual necessity, but their location and arrangement requires no great change to be made in the plan.

Figure 14 represents the arrangement of a floor in a ten story house in New York. This one is situated on a corner, with the main rooms ranged along the street fronts and the lesser ones arranged around the court; thus producing a hollow square as the block plan. The hollow being separated into two courts by the main stairway and elevator shaft.

This building has been very suceessful as an investment and, with the exception of the inner rooms on the lower stories, is quite a successful design in general, though the parlors are too distant and the bath rooms too close to the entrance from the public hall in about one-half of the suites.

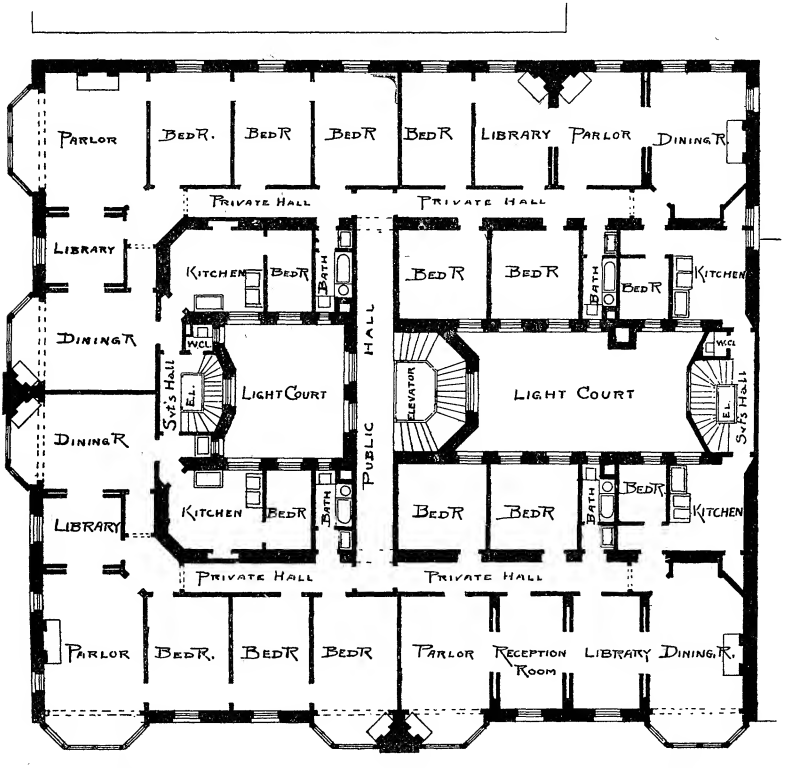


FIG. 14, Plan of Upper Stories of an Apartment House in New York, N. Y.

The connections between the kitchens and dining rooms and the kitchens and service halls are worthy of special attention, for but few houses have them equally good.

In buildings of as high an order as this one is, closets are seldom arranged in the usual way, but china closets, refrigerators and wardrobes are fixed in place and correspond to the general finish used in the various rooms. There are advantages worthy of notice in this provision.

A separate water closet, for the use of servants, is arranged in the rear hall; in this way a single closet is made to serve two apartments, and this effects a great saving in the plumbing, which is always an expensive item in city houses.

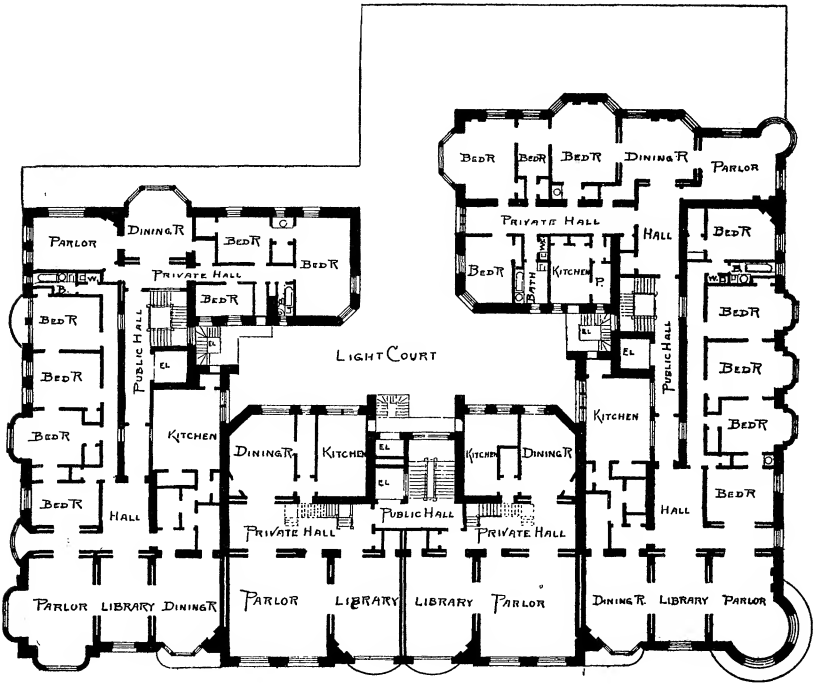


FIG. 15. Plan of Upper Stories of an Apartment House in New York, N. Y.

Figure 15 shows the plan of another and much better arranged house of this same class. This is is also ten stories in height and located in New York. In this case there are three street fronts, giving exceptional advantages for a favorable disposition of rooms, and the plan shows how fully these advantages were appreciated.

The necessary light court has been very ingeniously arranged and the minor rooms so disposed about it as to assure good light and ventilation in each, throughout the entire height of the building.

The main stairs, elevators and public halls are also in veyr

favorable locations and well lighted. The service stairs and elevators are upon the outside of the building, in very close connection with the kitchens of the several suites. This latter arrangement is often used, for, by making the stairways of iron, they answer the purpose of fire escapes, and have the advantage of being in positions well known and accessible to all the occupants of the house.

The general arrangement of the rooms of each separate apartment is excellent. A large reception hall in each opens from the public corridor and is in direct connection with the main rooms. Leading from this hall a private corridor gives access to the bed and bath rooms of each suite; these are well placed, regarding each other, and the former are well supplied with clothes closets. The kitchens and dining rooms are favorably situated and have ample pantry and closet room.

In the central part of the building, where the available space was not suitable for an apartment on each floor, an arrangement in which part of two stories is devoted to each is introduced; the main rooms are upon the lower floor and the bed and both rooms upon the floor above. A private stairway in each of these two suites connects these floors and completes the arrangement—which is admirably adopted, and formerly often used upon cramped or shallow sites.

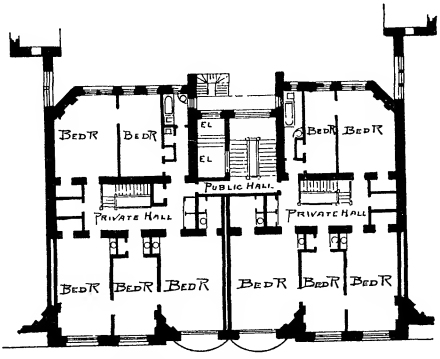
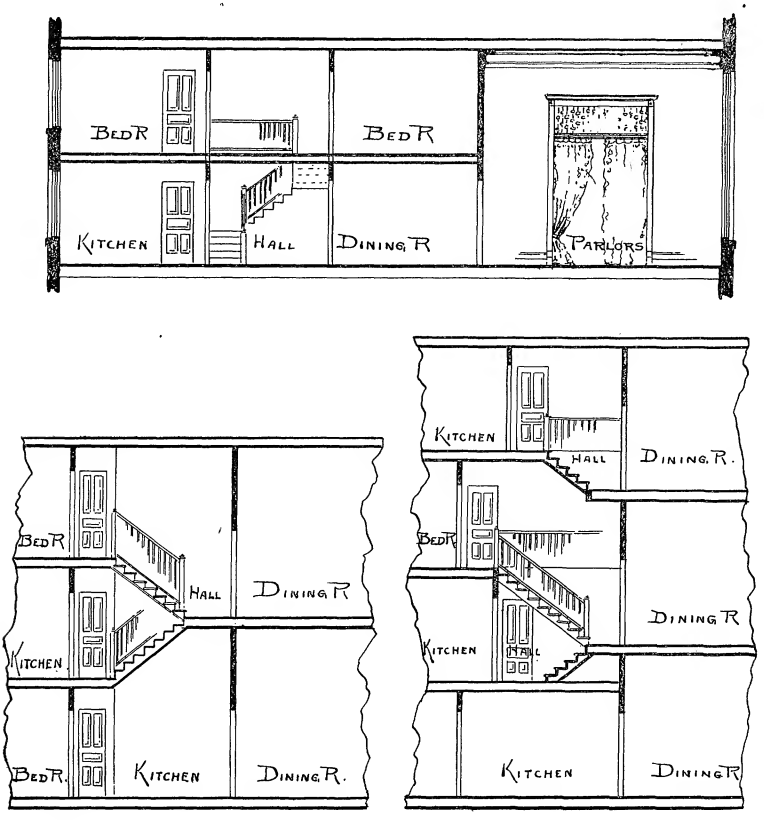


FIG. 16, Part plan showing 2nd story rooms in the "Two Story Apartments," in central part of building shown in Fig. 15.

The upper floor of this part of the house is shown in Figure 16. The other apartments on this floor remain essentially as on

the plan shown in the preceding figure. This two story arrangement is of French origin and was introduced into Boston and New York at about 1870. It is now but little used, though it has advantages for such cases as the present one.



FIGS. 17, 18 and 19. Arrangements of Stories in the "Duplex System."

Figures 17, 18 and 19 show arrangements for increasing the number of rooms without increasing the area devoted to an apartment. This is known as the "Duplex System" and consists of a multiplication of stories in that part of the house allotted to the minor rooms; which increase in number is accomplished by decreasing the height of each story.

The cuts show different dispositions of stories, but all on the same principle. The upper one—Figure 17—shows two stories

of minor rooms to one story for the principal uses, and this plan can be used only where the main room ceilings are of a considerable height, as in foreign houses. In this country its only application is in the case of a club house or hotel, as the usual apartment house ceiling is too low to permit of its use.

Figure 18 shows three stories in rear to two in front. By this arrangement the extra rooms may be connected with one or both suites. The cut shows them connected by the stairway with the upper one.

Figure 19 is the same as 18 excepting that the proportion is as 4 to 3. This is more applicable in cases where the ceiling of the main room is of ordinary height.

Variations of this "system" are found in both this and foreign countries, but, at the present time, the ceilings of American houses are too low to offer opportunity for its employment, except in rare instances.

All the plans shown in this article are taken from architectural works published in the country where the buildings were designed and erected, and with the exception of the French designs, they indicate the ability with which this class of work is executed. The American plans are from such papers as "*The Building Budget*," "*Inland Architect and Builder*," "*Northwestern Architect*," "*Inland Architect and News Record*," and "*The American Architect and Building News.*"

All of the American houses are heated by steam; the boiler being in charge of the janitor, whose duties include the keeping of the public halls, stairways, passages and walks in a clean and neat condition. The use of steam as a means of heating, is in part responsible for the smallness of the rooms in many apartments, and if the tendency to decrease their size increases, it may soon be advisable to use feather-weight wall paper, so as not to curtail their area to any very appreciable extent.

The following statement is from the "*American Architect*" of Jan. 10, 1891: "The planning of apartment houses is, moreover, almost a department by itself, requiring special study and experience; and architects, even of distinguished skill, who imagine that they can design such buildings successfully by the light of nature, without taking the trouble to study what has been done before them, often make lamentable failures."

BOOKS RECEIVED.

COX'S CONTINUOUS CURRENT DYNAMOS AND MOTORS: Their Theory, Design and Testing. With sections on Indicator Diagrams, Properties of Saturated Steam, Belting Calculations, etc. An Elementary Treatise for Students New York: The W. J. Johnston Company, Limited, 41 Park Row (Times Building) 1893. 271 pages, 83 illustrations. Price, $2.00.

This work, intended for students, gives the theory and design of continuous current dynamos and motors as understood and practiced in the designing room, and the methods of testing described are those of the factory testing room. The practical side of various questions treated is always kept in view, discussions having little bearing in this direction being excluded, as well as the descriptions of different machines and systems which are so often used to pad out the pages of similar treatises.

The first four chapters consist of a brief review of the electrical units and the general principles of the machines, and may be considered as an introduction to the subsequent portions; the higher branches of mathematics have been avoided here, as elsewhere. Chapter V is on calculations pertaining to the magnetic circuit. Chapter VI treats of the theory of windings, losses, etc., and Chapter VII of the special points to be observed in motor designing.

In Chapters VIII, IX and X, the application to the design of armatures, field magnets and motors of the principles developed in the preceding chapters is explained by reference to numerical problems selected so as to cover as broad a field as possible and show in what manner to make the various compromises always necessary in practical designing.

In Chapters XI and XII the methods of testing a completed machine and investigating its characteristics and the effect of various changes in design and operation are very fully discussed and illustrated by numerous curves.

As the subject of the steam engine is so closely allied to the testing and operation of dynamos and motors, the last two chapters are devoted to indicator diagrams and steam power calculations, which are treated in the same eminently practical manner as the purely electrical subjects.

The four appendices are on tests of irons, ampere turntables, determinations of sizes of wire for armatures and field coils, and on the calculation of belting.

With one exception all of the engravings were specially prepared for this work, and almost all of the numerous curves are reproductions of those obtained in actual commercial tests.

STANDARD TABLES FOR ELECTRIC WIREMEN: With Instructions for Wiremen and Linemen, Underwriters' Rules, and Useful Formulae and Data. By Chas. M. Davis. Fourth edition, thoroughly revised and edited by W, D. Weaver. Flexible morocco. 128 pages. Price, $1.00.

The third edition of this popular work was exhausted within a few months after its issue and the fourth edition has been delayed in order that it might contain the latest revisions of the Insurance Rules of the Underwriter's International Electric Association, now almost exclusively used in the United States. In addition to the above rules there has been added to this edition an important section on the calculation of alternating current wiring which, for the first time, brings this subject within the reach of practical men.

A number of the most important tables were prepared expressly for this work, and, being copyrighted, cannot be found elsewhere. Among these are the tables of alternating current wiring coefficients, those on limiting currents for exterior wiring and on the candle power of arc lamps, and the table enabling the ones for the three standard lamp voltages to be used for any voltage or drop, as well as several others including a complete set of wiring tables calculated on a uniform basis of 55-watt lamps.

The method of determining the sizes of conductors for incandescent wiring enables feeders, mains and branches to be proportioned as nearly exact as desired instead of only approximated to as by other methods. The wiring formulae for motor circuits, etc., are put in a simple and most practical form so as to be easily applied by any one. The formulae for horse power of engines and boilers are published here for the first time, and while they are based on rational principles, the different values of heating surfaces in boilers being considered, the results they give are the actual commercial ratings and not the theoretical horse power.

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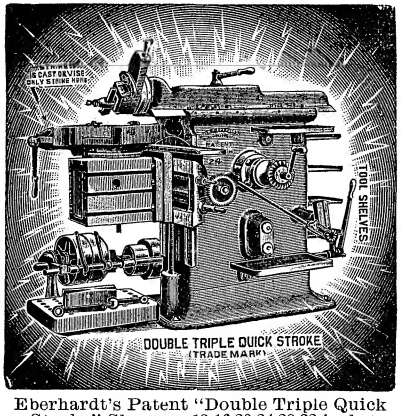

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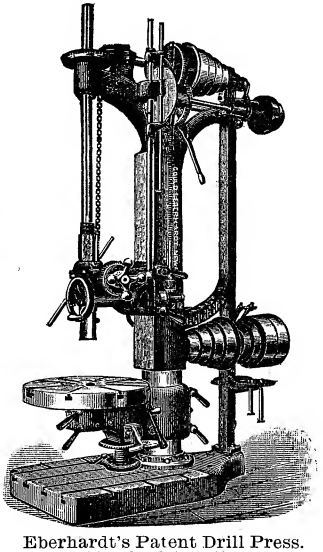
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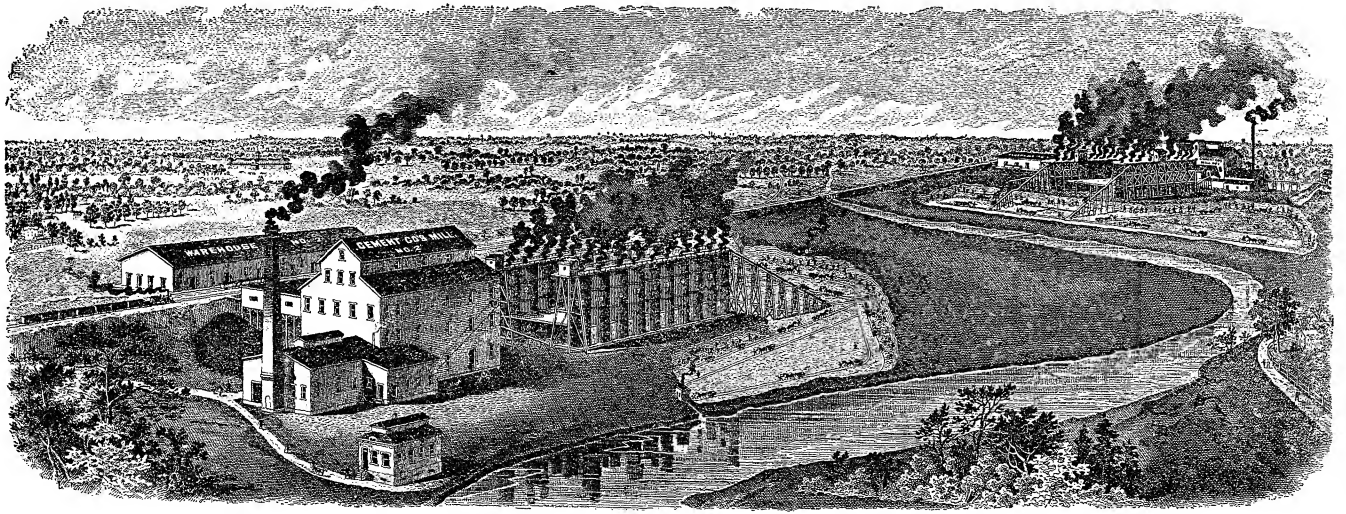
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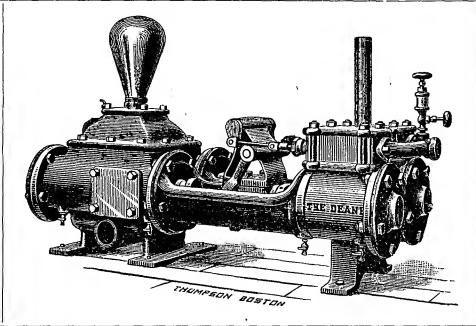
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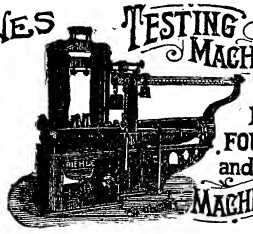
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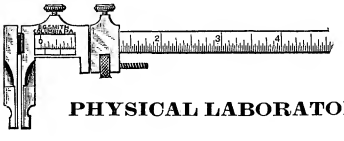
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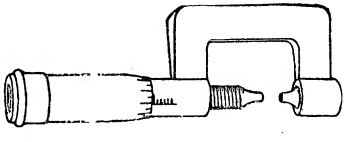
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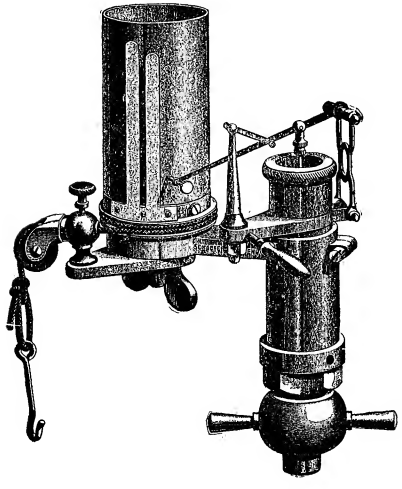
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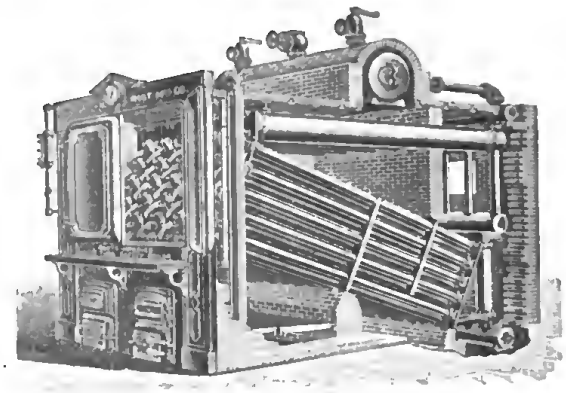
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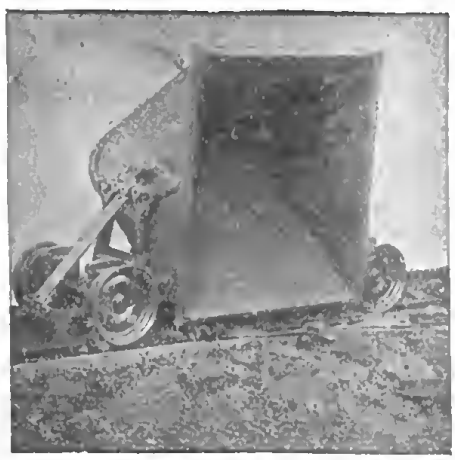


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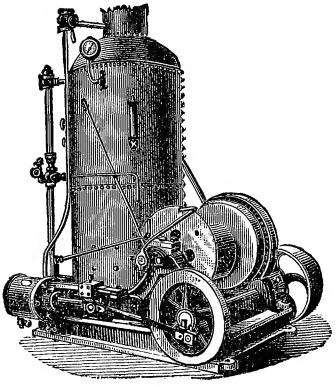
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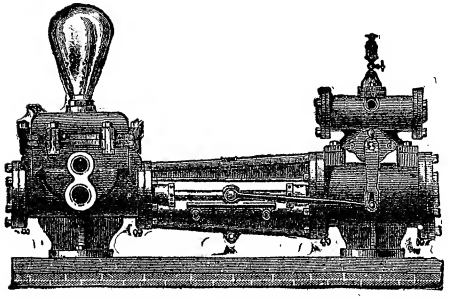
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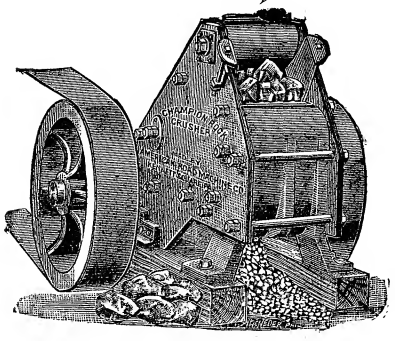
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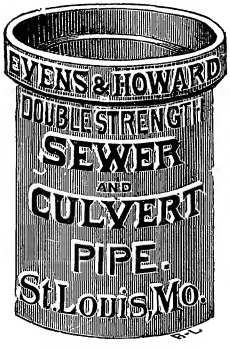
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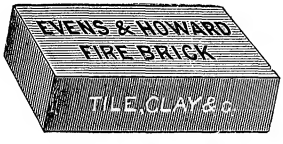
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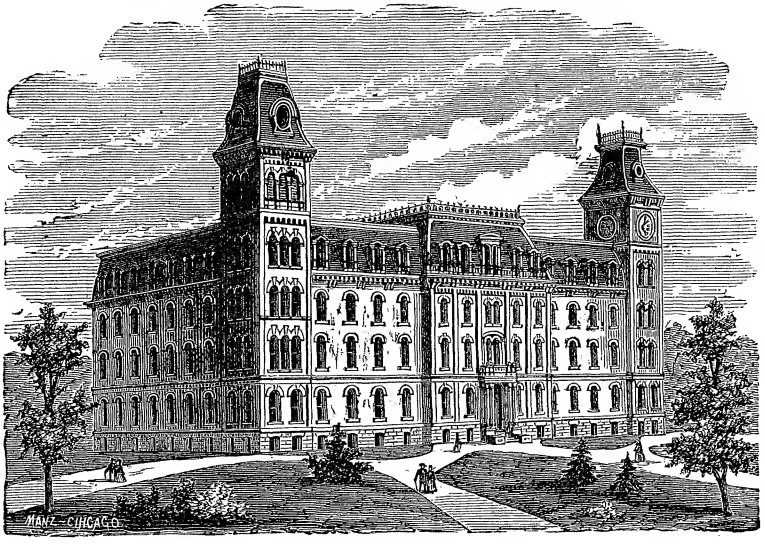
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(Signed). Geo. H. Barrus,
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Approved: John A. Roche,
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Copyist—A. M. C. *Date*—February 26, 1894.

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